Petroleum, Petrochemical, and Natural Gas Industries—Steam Turbines—Special-purpose Applications

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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 section or subsection indicates that either a decision is required or further information is to be provided by the purchaser. This information or decision should be indicated on the datasheets; otherwise it should be stated in the quotation request (inquiry) or in the order.

In this standard, where practical, U.S. Customary units have been included in brackets for information.

Petroleum, Petrochemical, and Natural Gas Industries—Steam Turbines—Special-purpose Applications

1 Scope

This standard specifies the minimum requirements for steam turbines for special-purpose applications for use in the petroleum, petrochemical, and natural gas industries. These requirements include basic design, materials, fabrication, inspection testing, and preparation for shipment. It also covers the related lube oil systems, instrumentation, control systems, and auxiliary equipment. It is not applicable to general-purpose steam turbines, which are covered in API 611.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 15, Guidelines for the Use of the International System of Units (SI) in the Petroleum and Allied Industries

API Standard 520, Part I, S*izing, Selection, and Installation of Pressure-relieving Systems in Refineries, Part I—Sizing and Selection*

API Recommended Practice 520, Part II, *Sizing, Selection, and Installation of Pressure-relieving Systems in Refineries, Part II—Installation*

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

API Standard 614, *Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries*

API Standard 670, *Machine Protection Systems*

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

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

ASME *Boiler and Pressure Vessel Code (BPVC)* [1], *Section V: Nondestructive Examination*

ASME *Boiler and Pressure Vessel Code (BPVC)*, *Section VIII: Pressure Vessels*

ASME *Boiler and Pressure Vessel Code (BPVC)*, *Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators*

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

ASME B16.1, Gray *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, and 250*

ASME B16.5, *Pipe Flanges and Flanged Fittings, NPS $^1/_2$ through NPS 24 Metric/Inch Standard*

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

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

ASME B17.1, *Keys and Keyseats*

ASME B31.3, *Process Piping*

[1] ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASTM A194 [2], *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A247, *Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings*

ASTM A278, *Standard Specification for Grey Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F (350 °C)*

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

ASTM A395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM A418, *Standard Practice for Ultrasonic Examination of Turbine and Generator Steel Rotor Forgings*

ASTM A472, *Standard Specification for Heat Stability of Steam Turbine Shafts and Rotor Forgings*

ASTM A536, *Standard Specification for Ductile Iron Castings*

AWS D1.1 [3], *Structural Welding Code—Steel*

EN 287 [4], *Qualification test of welders—Fusion welding—Part 1: Steels*

IEC 60045-1 [5], *Steam turbines—Part 1: Specifications*

IEC 60072, *Dimensions and output series for rotating electrical machines* (all parts)

IEC 60079, *Electrical apparatus for explosive atmospheres* (all parts)

IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems* (all parts)

IEC 61511, *Functional safety—Safety instrumented systems for the process industry sector* (all parts)

ISO 261 [6], *ISO General Purpose Metric Screw Threads—General Plan*

ISO 262, *ISO general-purpose metric screw threads—Selected sizes for screws, bolts and nuts*

ISO 724, *ISO general-purpose metric screw threads—Basic dimensions*

ISO 965 (all parts), *ISO general-purpose metric screw threads—Tolerances*

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

ISO 3744, *Acoustics—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 7005-1, *Pipe flanges—Part 1: Steel flanges for industrial and general service piping systems*

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

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[2] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
[3] American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.
[4] European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.
[5] International Electrotechnical Commission, 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.
[6] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

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 8821, *Mechanical vibration—Balancing—Shaft and fitment key convention*

ISO 15607 *Specification and qualification of welding procedures for metallic materials—General rules*

ISO 15649, *Petroleum and natural gas industries—Piping*

MSS SP-44 [7], *Steel Pipeline Flanges*

NEMA SM 24 [8], *Land-Based Steam Turbine Generator Sets 0 to 33,000 kW*

NFPA 70 [9], *National Electrical Code*

NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

SSPC-SP6 [10]/NACE No. 3 [11], *Commercial Blast Cleaning*

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply. (See Annex B for a guide to steam turbine nomenclature.)

3.1
alarm point
Preset value of a measured parameter at which an alarm is actuated to warn of a condition that requires corrective action.

3.2
anchor bolts
Bolts used to attach the mounting plate to the support structure or foundation.

3.3
axially split
Split with the principal joint parallel to the shaft centerline.

3.4
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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[7] Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, NE, Vienna, Virginia 22180-4602, www.mss-hq.com.

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

[9] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

[10] The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

[11] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77084-4906, www.nace.org.

3.5
control mechanism
All of the equipment between the speed governor and the governor-controlled valve(s) (such as linkages, pilot valves, power servos, and so forth).

3.6
critical speed
Shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.7
design
Manufacturer's calculated parameter.

NOTE This is 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.

3.8
duplex
The provision of two microprocessors instead of one in situations where a fail-over function is required.

NOTE Availability is typically in the 98 % range.

3.9
enclosure
Compartment designed to provide noise protection and/or weather protection.

NOTE The compartment can include walls, doors, and a roof.

3.10
fail safe system
System that causes the equipment to revert to a permanently safe condition (shutdown and/or depressurized) in the event of a component failure or failure of the energy supply to the system.

3.11
field changeable
Design feature that permits alteration of a function after the equipment has been installed.

NOTE The alteration can be accomplished by the following:

a) soldering jumper leads to terminal pins especially provided for this purpose,

b) employing circuit-board-mounted switches or potentiometers,

c) using a shorting or diode-pin-type matrix board,

d) using prewired shorting plugs,

e) using authorized controlled access.

3.12
gauge board
Bracket or plate used to support and display gauges, switches, and other instruments.

NOTE A gauge board is open and not enclosed. A panel is typically fully enclosed.

3.13
general-purpose turbine
Horizontal or vertical turbines used to drive equipment that is usually spared.

NOTE General-purpose steam turbines are intended for applications where the inlet gauge pressure does not exceed 4800 kPa (700 psi) and the inlet temperature does not exceed 400 °C (750 °F), and where the speed does not exceed 6000 r/min.

3.14
governor-controlled valve
Device that controls the flow of steam into or out of the turbine in response to the speed governor.

3.15
hold-down bolts
mounting bolts
Bolts that hold the equipment to the mounting plate or plates.

3.16
hydrodynamic bearings
Bearings that use the principles of hydrodynamic lubrication.

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.

3.17
informative
Information only.

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

3.18
internal friction damping
Damping effect that causes a phase difference between the stress and strain in any material under cyclic loading.

NOTE This phase difference produces the characteristic hysteric loop on a stress-strain diagram and is thus a destabilizing damping force.

3.19
local
(Device) mounted on or near the equipment or console.

3.20
manufacturer
Organization responsible for the design and manufacture of equipment.

NOTE The manufacturer is often a different entity than the vendor.

3.21
maximum allowable speed
Highest speed at which the manufacturer's design permits continuous operation.

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

3.22
maximum allowable temperature
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at any specified operating conditions.

3.23
maximum allowable working pressure
Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the maximum allowable temperature.

3.24
maximum continuous speed
Highest speed at which the turbine, as built and tested, is capable of continuous operation, at any of the specified steam conditions.

3.25
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 casing is subjected to the maximum temperature and pressure under these conditions.

3.26
maximum exhaust pressure
Highest exhaust steam pressure at which the turbine is required to operate continuously.

3.27
maximum inlet pressure and temperature
Highest inlet steam pressure and temperature conditions, at the inlet to the trip and throttle valve, at which the turbine is required to operate continuously.

3.28
maximum sealing pressure
Highest pressure the seals are required to seal during any specified static or operating conditions and during start-up and shutdown.

3.29
minimum allowable speed
Lowest speed at which the manufacturer's design permits continuous operation.

3.30
minimum exhaust pressure
Lowest exhaust steam pressure at which the turbine is required to operate continuously.

3.31
minimum inlet pressure and temperature
Lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.32
mounting plate
An intermediate plate or structure that is designed to simplify mounting and attachment of equipment to the foundation or to another steel structure. This is either a baseplate(s) or soleplates.

3.33
nominal pipe size
NPS
Dimensionless value approximately equal to the diameter in inches.

3.34
normal operating point
Point at which usual operation is expected and optimum efficiency is desired.

NOTE This point is usually the point at which the vendor certifies that performance is within the tolerances stated in this standard.

3.35
normal power
Turbine power at the normal operating point.

3.36
normative
Required.

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

3.37
observed (inspection or test)
Inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled even if the purchaser or his/her representative is not present.

3.38
owner
Final recipient of the equipment.

NOTE The owner can delegate procurement of the equipment to an agent.

3.39
panel
Enclosure used to mount, display and protect gauges, switches, and other instruments.

3.40
potential maximum power
Approximate maximum power to which the turbine can be uprated at the specified normal speed and steam conditions when it is furnished with suitable (i.e. larger or additional) nozzles and, possibly, with a larger governor-controlled valve or valves.

3.41
pressure casing
Composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

3.42
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.

3.43
radially split
Split with the principal joint perpendicular to the shaft centerline.

3.44
rated power
Greatest turbine power specified and its corresponding speed; it includes all the margin required by the specifications of the driven equipment.

3.45
rated speed
100 % speed
Highest rotational speed required to meet any of the specified operating conditions.

3.46
relief valve set pressure
Pressure at which a relief valve starts to lift.

3.47
remote
(Device) located away from the equipment or console, typically in a control room.

3.48
separation margin
Margin between a critical speed and the nearest required operating speed.

3.49
shutdown set point
Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.50
slow roll
Speed recommended by the vendor (typically, 500 r/min to 800 r/min) for warm-up and initial check of equipment integrity prior to full operation.

3.51
special-purpose turbines
Horizontal turbines used to drive equipment that are usually not spared and are used in uninterrupted continuous operation in critical service.

NOTE This category is not limited by steam conditions, power or turbine speed.

3.52
special tool
Tool that is not a commercially available catalogue item.

3.53
stability analysis
Determination of the natural frequencies and the corresponding logarithmic decrement of the damped rotor and support system using a complex eigenvalue analysis.

3.54
stage
One set of stationary and rotating blade rows.

3.55
synchronous tilt pad coefficient
Coefficient derived from the complex frequency-dependent coefficients with the frequency equal to the rotational speed of the shaft.

3.56
steam rate
Quantity of steam required by the turbine per unit of power output measured at the output shaft of the turbine.

3.57
triple modular redundancy
TMR
The provision of three microprocessors instead of one in situations where continuing functioning has to be ensured. Availability is typically in the 99.9999 % range.

3.58
trip speed
Rotational speed at which the independent overspeed shutdown system operates to shut down a turbine.

NOTE Trip speed is usually expressed in revolutions per minute.

3.59
unit responsibility
Responsibility for coordinating the documentation, delivery, and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

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

3.60
vendor
supplier
Agency that supplies the equipment in response to the order.

NOTE The vendor may be the manufacturer of the equipment or the manufacturer's agent and is normally responsible for service support.

3.61
witnessed (inspection or test)
Inspection or test that the purchaser attends.

NOTE A hold is applied to the production schedule and the inspection or test is carried out with the purchaser or purchaser's representative in attendance.

4 General

4.1 Unit Responsibility

The vendor who has unit responsibility shall ensure that all sub-vendors comply with the requirements of this standard.

4.2 Dimensions

- Drawings and maintenance dimensions shall be in SI units or U.S. customary (USC) units. Use of a SI datasheet indicates that SI units shall be used. Use of a USC datasheet indicates that USC units shall be used. Typical datasheets in both systems of units are given in Annex A.

4.3 Unit Conversion

The factors in API *MPMS* Ch. 15, shall be used to convert between USC units and SI units.

4.4 Nomenclature

A guide to steam turbine nomenclature is presented in Annex B.

4.5 Conflicting Requirements

In the event of conflict between this standard and the enquiry, the enquiry shall govern. At the time of the order, the order shall govern.

5 Statutory Requirements

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

6 Basic Design

6.1 General

● **6.1.1** The purchaser shall specify the period of uninterrupted continuous operation, during which time the equipment should not require shutdown to perform maintenance or inspection.

NOTE It is recognized that achievement of this objective requires a joint effort of the purchaser, vendor, and user.

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

6.1.3 The vendor who has unit responsibility shall ensure that all sub-vendors comply with the requirements of this standard.

● **6.1.4** The purchaser shall specify the equipment's normal operating point and any other required operating points, including the inlet and exhaust steam conditions and any extraction or induction steam quantities and pressures. The purchaser shall also specify the maximum and minimum values of the inlet, exhaust, and extraction/induction steam conditions.

6.1.5 Unless otherwise specified, steam purity limits shall be in accordance with IEC 60045-1 and NEMA SM 24.

6.1.6 Variations from maximum inlet steam pressure and maximum inlet steam temperature can be expected for short durations. Allowable swings and time durations over a 12 month period are defined in NEMA SM 24. The turbine shall be capable of withstanding these variations.

6.1.7 For generator drive applications in which process steam to or from the turbine is associated with a critical service need or if the power required from the turbine generator is specified as critical service, this standard may invoke.

6.1.8 Turbines shall be capable of the following:

a) operation at normal power and speed with normal steam conditions, with the steam rate certified by the manufacturer at these conditions;

b) delivering rated power at its corresponding speed with coincident minimum inlet and maximum exhaust conditions specified;

NOTE To prevent oversizing or to obtain higher operating efficiency or both, it may be desirable to limit maximum turbine capability by specifying normal power or a selected percentage of rated power instead of rated power at the conditions specified.

c) continuous operation at maximum continuous speed and at any other speed within the range specified, with a maximum continuous speed of at least 105 % of rated speed;

d) continuous operation at rated power and speed with maximum inlet steam conditions and maximum or minimum exhaust steam conditions;

e) continuous operation at the lowest speed at which maximum torque is required with minimum inlet and maximum exhaust conditions, with the purchaser specifying both the speed and torque values required;

f) continuous operation at specified conditions for extraction and/or induction;

g) operation with variations from rated steam conditions and steam purity levels recommended in IEC 60045-1 or NEMA SM 24;

NOTE Regardless of the design limit of any turbine component, the turbine should not be operated or rerated outside the nameplate limits without a thorough design review.

h) operation uncoupled with maximum inlet steam conditions.

Governing instability and high acceleration rates can occur and may require action such as throttling of the inlet pressure. Care should also be taken when operating at no or light load (in any turbine section) and high speed or uncoupled, as typically applicable for generator sets, but occasionally also applicable to mechanical drive applications. This type of operation may require reducing the inlet temperature to keep exhaust and/or extraction temperature within acceptable limits for the turbine, piping, and (if applicable) condenser. One concern that should be evaluated is the risk of the rotor expansion above the normal case when the turbine is operated at high exhaust temperatures.

6.1.9 Equipment shall be designed for operation at momentary speeds up to the trip speed without damage. The turbine trip speed shall be 110 % of maximum continuous speed, normally 116 % of rated speed. For generator drive, trip speed is 10 % above synchronous speed.

This requirement should not be construed to allow continuous operation above maximum continuous speed.

6.1.10 The turbine and accessories shall perform on the test stand and when installed on the permanent foundation within the specified acceptance criteria. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

● **6.1.11** If specified, the vendor's representative shall witness:

a) a check of the piping alignment performed by unfastening the major flanged connections of the equipment;

b) the initial shaft alignment check;

c) shaft alignment at operating temperature.

NOTE 1 Many factors can adversely affect site performance. These factors include such items as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site.

NOTE 2 Further information on machinery installation and installation design is given in API 686.

6.1.12 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.

6.1.13 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 may be accomplished by the use of shouldering, cylindrical dowels, or keys.

6.1.13.1 Any maintenance item with a mass more than 20 kg (44 lb) shall be provided with lifting lugs or similar dedicated fixed lifting point(s). Screw-in eyebolts are only acceptable for bearing housing covers and for internal components where other lifting arrangements are impractical. Holes for eyebolts shall be permanently marked with the correct bolt size to be used. If this marking is impractical, bolt size information shall be clearly indicated in the instruction manual.

6.1.14 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 or idleness.

6.1.15 Unless otherwise specified, cooling water systems shall be designed for the conditions specified in Table 1. Provision shall be made for complete venting and draining of the system.

Table 1—Design Criteria and Specifications for Cooling Water Systems

Criteria	SI Units	USC Units
Water velocity over heat exchanger surfaces	1.5 m/s to 2.5 m/s	5 ft/s to 8 ft/s
Maximum allowable working pressure, gauge	700 kPa	100 psi (7 bar)
Test pressure (1.3 MAWP), gauge	1050 kPa	150 psi (10.5 bar)
Maximum pressure drop	100 kPa	15 psi (1 bar)
Maximum inlet temperature	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Maximum temperature rise	20 K	30 °F
Minimum temperature rise	10 K	20 °F
Fouling factor on water side	0.35 m^2·K/kW	0.002 hr-ft^2-°F/Btu
Shell corrosion allowance	3.0 mm	$^1/_8$ in.
NOTE The criterion for velocity over heat exchange surface is intended to minimize waterside fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water.		

6.1.16 The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflicting design. If such a conflict exists, the purchaser shall approve the final selection.

● **6.1.17** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable SPL specified. The vendor shall provide details of any special measures taken to achieve the stated levels. The vendor shall ensure these noise limits are specified to all sub-suppliers.

In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for each principal component supplied.

● **6.1.18** 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 sections of IEC 60079 or NFPA 70, Articles 500, 501, 502, and 504, as well as any local codes specified (and, if requested by the vendor, furnished) by the purchaser.

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

- **6.1.20** The equipment, including all auxiliaries, shall be suitable for operation, using the utility conditions specified by the purchaser.

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

6.2 Nameplates and Rotation Arrows

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

6.2.2 Rotation arrows shall be cast in, or attached to, each major item of rotating equipment at a readily visible location. Welding is not permitted. A rotation arrow shall be located on the thrust-bearing housing.

6.2.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper alloy. Attachment pins shall be of the same material.

6.2.4 Data shall be clearly stamped on the nameplate and shall include, but not be limited to, the following:

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

b) vendor's name;

c) year ship;

d) serial number;

e) size and type;

f) rated power and speed;

g) all lateral critical speeds less than trip speed;

h) the next lateral critical speed greater than trip speed;

i) maximum continuous speed;

j) trip speed;

k) normal and maximum inlet steam temperature and pressure;

l) normal and maximum exhaust steam pressure;

m) number of teeth in the multi-toothed surface provided for speed sensing.

6.2.5 Any lateral critical speeds determined from mechanical running tests shall be stamped on the nameplate followed by the word "Test." Critical speeds, predicted by calculation, up to and including the first critical speed above trip speed, and not identifiable by test, shall be stamped on the nameplate followed by the abbreviation "Calc."

7 Casings

7.1 Pressure Casings

7.1.1 All pressure parts shall be suitable for operation at the most severe conditions of coincident pressure and temperature predicted with the specified steam conditions.

7.1.2 Pressure casing material stress shall comply with 7.1.2.1, 7.1.2.2, or 7.1.2.3. The manufacturer shall state the source of the material properties, such as ASTM or ASME, as well as the casting factors applied, in their proposal. The NDE requirements for various casting quality factors shall be determined from the published material properties or be equivalent to those required by ASME *BPVC*, Section VIII, Division 1.

7.1.2.1 Any material's tensile stress used in the design of the pressure casing shall not exceed 25 % of the minimum ultimate tensile strength for that material at the maximum specified operating temperature, multiplied by the appropriate casting quality factor.

NOTE To provide the initial load required to obtain a reliable bolted joint, the bolting may be tightened to produce a bolt tensile stress that exceeds 25 % of its ultimate tensile stress. Values in the range of 70 % of yield are common.

7.1.2.2 Any material used for pressure casings shall not exceed its maximum allowable stress at the maximum specified operating temperature, and, for castings, multiplied by the appropriate quality factor. The material maximum allowable stress and casting quality factor shall be defined per ASME *BPVC*, Section VIII, Division 1, Part UG-27 and Part UG-24, respectively.

7.1.2.3 Pressure-containing components may be designed with the aid of finite element analysis provided that the design limits comply with Section VIII, Division 2 of the ASME *BPVC* stress intensity as modified by Equation (1).

$$I_{\mathrm{MAS}} = I_{\mathrm{CS}}\left(\frac{P_{\mathrm{ch}}}{150}\right) \quad (1)$$

where

I_{MAS} is the maximum allowable stress intensity in kPa (psi);

I_{CS} is the code stress intensity in kPa (psi);

P_{ch} is the code hydrotest pressure in percent of MAWP.

7.1.3 The relief valve set pressure(s) shall be set no higher than the casing maximum allowable working pressure. For condensing turbines, the exhaust casing shall be designed for both full vacuum and for a maximum allowable working gauge pressure of at least 70 kPa (10 psi).

A full-capacity safety relief valve shall be installed in the exhaust piping between each exhaust connection and exhaust block valve to prevent overpressure and possible rupture of the turbine casing. For condensing turbines where there is no exhaust block valve, the relief valve may be located on the condenser.

Unless otherwise specified, the purchaser shall provide the safety relief valve(s). These relief valves are to be installed in the purchaser's piping and may affect the piping design.

7.1.4 The vendor shall define the maximum allowable working pressure of the turbine casing and of each part of turbine casings designed for more than one maximum allowable pressure level (split-pressure-level casings). The exhaust of condensing turbine shall be capable of short-term running at 150 °C (300 °F).

NOTE During operation with poor vacuum or no load testing, the exhaust temperature will rise. This value is to ensure the turbine can operate in either of these conditions.

7.1.5 The turbine casing shall be axially split. Turbine casings may also be split radially between high-pressure and low-pressure sections. Where possible, vertical joints in the turbine casing shall be discontinuous at the horizontal split to avoid a four-cornered joint.

7.1.6 The main joint of axially and radially split casings shall use a metal-to-metal joint that is tightly maintained by bolting. The joint shall be sealed with a compound that is compatible with the fluids to be handled. Gaskets (including string type) shall not be used.

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

If the clearances vary from the closed casing readings, they shall be confirmed to be within manufacturer's allowable clearance tolerance and guidelines.

7.1.8 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change in the relative position of the shaft ends caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 μm (0.002 in.), see 7.4.

NOTE This section does not apply to thermal growth.

7.1.9 Supports, and the design of jackscrews and their attachments, shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews without flexing and damage of the support plates and jackscrews.

7.1.10 Jackscrews, guide rods, cylindrical casing-alignment dowels, and/or other appropriate devices shall be provided to facilitate disassembly and reassembly. Guide rods shall be of sufficient length and rigidity to prevent damage to the internals or casing studs by the casing during disassembly and reassembly. Lifting lugs shall be provided for lifting only the top half of the casing.

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

7.1.12 The steam chest and casing shall be provided with connections to ensure complete drainage. Drain connections shall be DN 25 (NPS 1) minimum size.

7.1.13 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 any allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1.5 times the stud diameter. Through bolting is preferred in areas of the casing where the temperature may exceed 410 °C (770 °F).

7.1.14 Studded connections shall be furnished with studs installed. The first 1.5 threads at both ends of each stud shall be removed.

7.1.15 Bolting shall be furnished as follows.

a) The details of threading shall conform to ISO 261, ISO 262, ISO 724, and ISO 965, or ASME B1.1.

b) Studs or through bolts shall be supplied on the main joint of axially split casings and end covers of radially split casing joint(s).

c) Studs or through bolts 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.

d) The manufacturer's marking, in accordance with the appropriate standard (e.g. ASTM), shall be located on all fasteners 6 mm ($^1/_4$ in.) and larger (excluding washers and headless set screws). For studs, the marking shall be located on the nut end of the exposed stud.

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

● f) If specified, the main casing joint studs and nuts shall be designed for the use of hydraulic bolt tensioning. The vendor shall provide procedures and any special tooling required.

g) Internal socket-type, slotted-nut, or spanner-type bolting shall not be used on the exterior of the turbine case unless specifically approved by the purchaser.

h) The vendor shall provide a bolt torque schedule for main horizontal joint, valve chest (if bolted to the casing), and exhaust, which shall detail the bolt torque requirements and tightening patterns. ASME flanges shall be torque in accordance with ASME B31.3.

7.1.16 Mounting surfaces shall meet the following criteria.

a) The surface finish shall be 6 µm (250 µin.) arithmetic average roughness, Ra, or better.

b) The mounting surfaces in one plane shall be machined such that no point on any surface deviates from the common plane by more than 50 µm (0.002 in.).

c) The different mounting planes shall be parallel to each other within 1 in 1000, in any direction.

d) The upper surfaces shall be machined or spot faced to a diameter larger than the bolt head, nut, or washer, parallel to the mounting surface.

e) Unless the manufacturer provides special tools, mounting surfaces shall be designed to accept standard tools.

7.1.17 Hold-down bolt holes shall be drilled perpendicular to the mounting surface(s) and shall be 15 mm (0.6 in.) larger in diameter than the hold-down bolt. Holes shall be machined or spot faced to a diameter suitable for a fully eccentric washer next to the hole to allow for equipment alignment. Holes shall not be slotted.

7.1.18 The equipment feet shall be provided with vertical jackscrews and shall be drilled with pilot holes that are accessible for use in final doweling if required.

7.1.19 If casing expansion keys and slide surfaces are used, the vendor shall provide a suitable material combination that prevents sticking during transient and normal operating conditions. Vendor shall provide details regarding their design, location, and materials of construction.

7.2 Casing Connections

● **7.2.1** The purchaser shall specify the orientation of the main inlet and outlet steam connections. All connections shall be suitable for the maximum allowable working pressure(s) of the casing. Flanged connections shall 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 weld-neck or socket-weld flange.

7.2.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping (see 11.3.4). All welding of connections shall be completed before the casing is hydrostatically tested (see 16.3.2).

7.2.3 Casing openings for piping connections shall be at least DN 20 (NPS $^3/_4$) and shall be flanged or machined and studded. Flanged connections shall be installed as follows.

a) Pipe nipples shall be provided with a weld-neck or socket-weld flange.

b) The nipple and flange materials shall meet the requirements of 7.2.2.

7.2.4 Pipe nipples 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). Bracing or reinforcement is required when nipples longer than 150 mm (6 in.) are necessary.

7.2.5 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.

7.2.6 Steel flanges shall conform to ISO 7005-1 Series 1 or ISO 7005-2 Series 1 [or ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47 (Series B)], as specified. Flanges other than those covered in ISO 7005-2 shall conform to the dimensional requirements specified above.

ISO 7005-1 (steel flanges) PN 20, PN 50, PN 110, PN 150, PN 260, and PN 420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges. ISO 7005-1 flanges are not identical to ASME B16.5 and MSS SP-44 flanges but are deemed to comply with the dimensions specified in the ASME B16.5 and MSS SP-44. ISO PN 2.5 and PN 6 do not have a corresponding ASME class, and ASME Classes 75, 400, and 800 do not have corresponding ISO PN designations. These PN and class flange ratings should therefore not be used.

7.2.6.1 The concentricity of the bolt circle and the bore of all casing flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

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

● **7.2.6.3** If ISO 7005-1 has been specified, materials shall be in accordance with ISO 7005-1 as specified. The pressure temperature ratings shall correspond to the materials specified.

7.2.6.4 For all steel flanges, imperfections in the flange facing finish shall not exceed those permitted by ASME B16.5 or ASME 16.47 as applicable.

7.2.6.5 Flat face flanges with full raised face thickness are acceptable on casings of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ANSI are acceptable. Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing.

7.2.7 Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1 or ISO 7005-2 (or ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47).

7.2.8 Machined and studded connections and flanges not in accordance with ISO 7005-1:1992 or ISO 7005-2:1988 (or ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47) require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs, and nuts for these nonstandard connections.

7.2.9 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel to the plane of the flange as 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.

7.2.10 All of the purchasers' connections shall be accessible for disassembly without requiring the steam turbine, any major part, or attached auxiliary piping to be moved.

● **7.2.11** If specified, appropriate casing connections with valves shall be provided for an inert gas blanket to be used as preservation during long periods of standstill.

7.2.12 The exhaust casing on condensing turbine shall be designed with adequate inspection openings for blade inspection and maintenance access to the exhaust hood. Machined and studded or flanged connections shall be required for inspection openings.

● **7.2.13** If specified, permanent connections with valves shall be provided to provide wet and dry preservation of the steam turbine during stand still.

7.3 Internal Stationary Components

7.3.1 All control stage nozzle rings shall be replaceable. Nozzle rings welded to the outer casing are acceptable only when approved in advance by the purchaser.

7.3.2 All noncontrol stage stationary blading shall be mounted in replaceable diaphragms or blade carriers. Nozzles or blades welded to the diaphragm are preferred. Partial blading at the diaphragm split line shall be designed to prevent failure of the thin part of the blading during turbine operations.

7.3.3 Any internal fasteners shall be positively retained to prevent them from entering the steam path.

7.3.4 The design shall ensure that water cannot be trapped in the wet region of a condensing turbine. The design of water drain holes in the wet region of a condensing turbine shall avoid the holes becoming blocked by corrosion or debris. In the case of drain holes in the diaphragms of an impulse type turbine, this shall be achieved by lining the drain holes with corrosion-resistant material.

7.3.5 All diaphragms, blade carriers, or other inner casings shall be designed with vertical leveling and positioning lugs or shims located near the horizontal split line. Radial ground crush pins shall not be used to set the alignment. On condensing sections of reaction machines the diaphragms may be bolted to the exhaust casing. The vendor shall indicate the required assembly vertical and horizontal clearances for each diaphragm or blade carrier

7.3.6 Packing holders for shaft end seals shall be designed with vertical leveling lugs located near the split line for adjustment. If adjustable packing holders are not supplied, the vendor shall define how the clearances can be adjusted during future maintenance. Manufacturer shall provide information and data that defines how future changes can be made and the relationship between the changes and final packing clearances.

7.3.7 Turbines operating on saturated steam shall have components in the steam path (e.g. nozzles, blading, diaphragms) made of erosion-resistant materials or appropriate coatings applied.

7.3.8 Provisions shall be made to minimize water cutting of wet stages at the horizontal joint and the diaphragm steam face. Options to minimize the problem include stainless steel inlay or inserted rings.

7.3.9 Shaft seals or packing and inter-stage diaphragm seals shall be bronze, nickel bronze, stainless steel, or other suitable materials agreed upon by the purchaser and the turbine manufacture. Gray cast iron and Ni-resist diaphragm seals are prohibited.

7.4 External Forces and Moments

7.4.1 Turbines shall be designed to withstand external forces and moments at least equal to the values calculated in accordance with NEMA SM 24.

7.4.2 The turbine supplier shall tabulate the allowable forces and moments for each casing connection.

7.5 Material Inspection of Pressure Casing

NOTE 1 Refer to 16.2.2 for inspection of non-pressure-containing parts.

NOTE 2 Refer to 3.41 for the definition of pressure casing.

7.5.1 Regardless of the generalized limits presented in this section, it shall be the vendor's responsibility to review the design limits of all materials and welds in the event that more stringent requirements are specified. Defects that exceed the limits imposed in 7.5.9 shall be removed to meet the quality standards cited, as determined by additional magnetic particle or liquid penetrant inspection as applicable before repair welding.

● **7.5.2** If radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required by the ASME *BPVC* or specified, the procedures and acceptance criteria in Table 2 shall apply, except as required by 7.5.4. Alternative standards may be proposed by the vendor for approval by the purchaser.

Table 2—Materials Inspection Standards for Pressure Casings

Type of Inspection	Methods	Acceptance Criteria	
		For Fabrications	For Castings
Radiography	Section V, Articles 2 and 22 of the ASME *Code*	Section VIII , Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the ASME *Code*	Section VIII, Division 1, Appendix 7 of the ASME *Code*
Ultrasonic inspection	Section V, Articles 4, 5, and 23 of the ASME *Code*	Section VIII, Division 1, UW53 and Appendix 12 of the ASME *Code*	Section VIII, Division 1, Appendix 7 of the ASME *Code*
Magnetic particle inspection	Section V, Articles 7 and 25 of the ASME *Code*	Section VIII, Division 1, Appendix 6 of the ASME *Code*	See acceptance criteria in Table 3
Liquid penetrant inspection	Section V, Articles 6 and 24 of the ASME *Code*	Section VIII, Division 1, Appendix 8 of the ASME *Code*	Section VIII, Division 1, Appendix 7 of the ASME *Code*
Visual inspection (all surfaces)	ASME *Code*, Section V, Article 9	In accordance with the material specification and the manufacturer's documented procedures	MSS SP-55

7.5.3 The purchaser shall be notified before making a major repair to a pressure-containing part. Major repairs, for the purpose of purchaser notification only, is any defect that equals or exceeds any of the three criteria defined below.

1) The depth of the cavity prepared for repair welding exceeds 50 % of the component wall thickness.

2) The length of the cavity prepared for repair welding is longer than 150 mm (6 in.) in any direction.

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

7.5.4 All repairs to pressure-containing parts shall be made as required by the following documents.

1) The repair of plates, prior to fabrication, shall be performed in accordance with the ASTM standard to which the plate was purchased.

2) The repair of castings or forgings shall be performed prior to final machining in accordance with the ASTM standard to which the casting or forging was purchased.

3) The repair of a fabricated casing or the defect in either a weld or the base metal of a cast or fabricated casing, uncovered during preliminary or final machining, shall be performed in accordance with Table 2.

7.5.5 Plate used in fabrications shall be 100 % ultrasonic inspected prior to starting fabrication in accordance with the ASTM standard to which the plate was purchased.

7.5.6 Spot radiography shall consist of a minimum of one 150-mm (6-in.) spot radiograph for each 7.6 m (25 ft) of weld on each casing. As a minimum, one spot radiograph is required for each welding procedure and welder used for pressure-containing welds.

7.5.7 For magnetic particle inspections, linear indications shall be considered relevant only if the major dimension exceeds 1.6 mm ($^1/_{16}$ in.). Individual indications that are separated by less than 1.6 mm ($^1/_{16}$ in.) shall be considered continuous.

7.5.8 Cast steel magnetic casing parts shall be examined by magnetic particle methods. Acceptability of defects shall be based on a comparison with the photographs in ASTM E125 Code. For each type of defect, the degree of severity shall not exceed the limits specified in Table 3.

Table 3—Maximum Severity of Defects in Castings

Type	Defect	Degree
I	Linear discontinuities	1 (Code all)
II	Shrinkage	2
III	Inclusions	2 (Code 3)
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

8 Rotating Elements

8.1 General

8.1.1 Rotors shall be capable of safe operation at momentary maximum overshoot speed of 127 % of rated speed at any specified operating conditions. Following such an excursion, the rotor shall be capable of operation without immediate maintenance intervention. For generator drives, rotors shall be capable of safe operation at momentary maximum overshoot speed of 121 % of synchronous speed at any specified operating condition.

NOTE Rubbing of seals and minor localized yielding of rotor components can occur and vibration levels can increase after such an event.

8.1.2 Rotors shall be of integrally forged construction. With purchaser's approval, built-up rotors (disks shrunk on the shaft) may be applied if blade tip velocities are less than 250 m/s (825 ft/s) at maximum continuous speed or if stage inlet steam temperatures are less than 440 °C (825 °F).

8.1.3 Each rotor shall be permanently marked with a unique identification number. This number shall be on the shaft end, in an area that is not prone to damage.

● **8.1.4** If specified, provisions shall be made for field balancing without disassembly of the turbine. The vendor shall describe these provisions and the method of use in the proposal.

8.1.5 Rotors shall be designed with an integral "flinger" between the bearing housings and gland seals to help prevent moisture from entering the bearing housing.

8.2 Shafts

8.2.1 Shafts shall be accurately finished throughout their entire length. The surface of the shaft at shrink fit areas and bearing areas shall be finished to a roughness not exceeding 0.8 µm (32 µin.) Ra.

8.2.2 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The surface shall be finished to a roughness not exceeding 0.8 μm (32 μin.) Ra. These areas shall be properly demagnetized to the levels specified in API 670 or otherwise treated so that the combined total electrical and mechanical runout does not exceed the following.

a) For areas to be observed by radial-vibration probes, 25 % of the allowed peak-to-peak vibration amplitude or 6.3 μm (0.25 mil), whichever is greater.

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

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

8.2.4 Shafts shall be capable of transmitting torque at least equal to the torque determined by potential maximum power at maximum continuous speed. The shaft end design shall conform to the requirements of API 671.

8.2.5 To prevent the buildup of harmful potential voltage, magnetic flux density of any part of the rotating element shall not exceed 0.0003 T (3 G).

8.2.6 The turbine vendor shall, jointly with the driven equipment vendor, establish the maximum transient torque value that can occur in the shafting system under start-up, running, and fault conditions. All components, including couplings, and fit of coupling hub on shaft, shall be suitable for at least 115 % of this value.

8.2.7 Plating shall not be used to correct manufacturing errors.

8.3 Blading

8.3.1 The vendor shall design each blade row analyzing potential resonances of the blades' natural frequencies or modes in the specified operating speed range with any harmonic of rotating speed, up to 15X rotating speed, and 1st and 2nd upstream vane passing frequency.

NOTE Excitation sources to be considered in the in the design analysis include—but are not limited to—first and second passing frequencies of upstream and downstream stationary blade rows, steam passage splitters, irregularities in vane pitch at horizontal casing flanges, the first four turbine speed harmonics, casing openings (exhaust or extraction), partial arc diaphragms or nozzle plates, internal struts and structural members in the inlet and exhaust casing or horizontal joints, and meshing frequencies in gear units.

8.3.2 The blade natural modes to be considered in the design analysis shall include at least the tangential (in-phase and out of phase), axial, and torsional modes, including, if applicable, packet (blades per banded group) modes. Blades' natural frequencies calculations shall include a correction for actual operating temperature and operating speed.

8.3.3 Blade design shall meet one of the following requirements.

a) Resonance shall not occur within 10 % of the excitation frequencies mentioned in 8.3.1.

b) If any resonance is possible, the relevant dynamic stresses for any specified operating condition shall be low enough to ensure continuous, trouble-free operation. This shall be assessed during the design phase according to the following methods:

   1) resonance dynamic stresses calculation and comparison with allowable limits (using Goodman, Haigh, or equivalent diagram) to check that the safety factor meets manufacturer's design practices;

2) resonance is acceptable according to the standard design practices of the manufacturer if the same type of blade and the same or scaled blade design has already been operated at the same or higher load in the same speed range.

c) Blades shall be designed to withstand operation at all resonances with relevant excitations encountered during normal start-up.

8.3.4 Prior to manufacturing, the manufacturer shall provide the following design data for each row of blades for the owner's review and acceptance:

a) steam bending stresses;

b) Campbell or Haigh or equivalent diagrams;

c) Goodman diagrams together with supporting computations showing total operating stress (steady state plus cyclic) of all blading for which resonant interference occurs within the normal operating speed range. The vendor shall also list the maximum allowable blade stresses.

8.3.5 All blades shall be mechanically suitable for operation (including transient conditions) over the specified speed range. The vendor shall assume that the driven equipment torque varies with the square of the speed, unless otherwise specified by the purchaser or by the vendor having unit responsibility.

8.3.6 Tenon holes in the shrouds shall be drilled or milled and finished with radii or chamfers on both sides of the holes.

8.3.7 Shrouds shall be rolled to the proper radius prior to fitting and shall be fitted to the blades and peened so that there are no gaps between the shrouds and the blades. The vendor shall state the method used for peening the tenons.

8.3.8 Prior to blade tenon peening, test peening shall be completed for each new tenon/shroud geometry and/or metallurgy. Procedure for qualifying the tenon peening process shall include the following to ensure consistent results.

8.3.8.1 Manufacture six "peening samples" from the same metallurgy and material properties of bar stock used to manufacture the blades. The samples shall have the tenon geometry machined into them, including diameter, height, fillet radius, and surface finish.

8.3.8.2 Manufacture a shroud sample using the same type of material used for the final shroud, including the hole tenon with all design features such as through diameter, corner radius adjacent to the top of blade, top of tenon hole chamfer, and surface finish.

8.3.8.3 Peen the tenons to the shroud using the peening process that will be used for peening of the rotor. If an automatic peening machine is used, record all settings, including but not limited to working pressure and travel.

8.3.8.4 NDE the peened tenons to check for cracks.

8.4 Speed-sensing Element

A dedicated multi-toothed surface for speed sensing shall be provided integral with, or positively attached and locked to, the turbine shaft. Other speed sensors may share this surface. The multi-toothed surface shall not be used as a gear for driving other mechanical components. The axial width of the multi-toothed surface (the width of the surface being viewed by radial probes) shall be a minimum of one and one-half times the diameter of the probe tip.

9 Rotordynamics

9.1 General

9.1.1 In the design of rotor-bearing systems, consideration shall be given to all potential sources of excitation, which shall include, but are not limited to, the following unbalance in the rotor system;

a) fluid destabilizing forces from bearings, seals, and aerodynamics;

b) internal rubs;

c) blade and nozzle passing frequencies;

d) gear-tooth meshing and side bands;

e) coupling misalignment;

f) loose rotor-system components;

g) internal friction within the rotor assembly;

h) synchronous excitation from complimentary geared elements;

i) control loop dynamics such as those involving active magnetic bearings;

j) 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 an excitation applied to a rotor-bearing-support system coincides with a natural frequency of that system, the system is 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.

NOTE 3 API 684 provides further information on rotordynamics.

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 required operating speed range or the specified separation margins (SM_r) (see 9.2.11). The effective stiffness and damping of the structural support shall be considered in the analysis of the rotor-bearing-support system [see 9.2.5 d)].

● **9.1.3** If specified, the vendor with unit responsibility shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. This shall be illustrated by the use of Campbell diagram, submitted to the purchaser for review and included in the instruction manual.

NOTE Examples of undesirable speeds are those associated with rotor lateral critical speed with amplification factors greater than or equal to 2.5, train torsional natural frequencies, and blading modes.

9.2 Lateral Analysis

9.2.1 Critical speeds and their associated amplification factors shall be determined by means of a damped unbalanced rotor response analysis. The results of the analysis shall be provided in report form. As a minimum the report should include the results of 9.2.3 through 9.2.14, and 9.3. See Figure 1.

9.2.2 The location of all critical speeds below the trip speed shall be confirmed on the test stand during the mechanical running test (see 9.4.1). The accuracy of the numerical model shall be demonstrated (see 9.4).

9.2.3 The vendor shall conduct an undamped analysis to identify the undamped critical speeds and determine their mode shapes. The analysis shall identify the first four undamped critical speeds and cover as a minimum the stiffness range from 0.1X to 10X the expected support stiffness.

9.2.4 The results of the undamped analysis performed in accordance with 9.2.3 shall be provided to the purchaser. The presentation of the results shall include:

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 (K_x) and vertical (K_y) (see Figure 2);

c) operating speed range showing N_{ma} and N_{mc}.

NOTE For machinery with widely varying bearing loads and/or load direction, the vendor may propose to substitute mode shape plots listing the undamped critical speed for each of the identified modes in lieu of the undamped critical speed map.

9.2.5 The damped unbalanced response analysis shall include, but shall not be limited to, the following:

a) rotor masses and polar and transverse moments of inertia, including coupling halves, and rotor stiffness;

b) bearing lubricant-film stiffness and damping values, including changes due to speed, load, preload, range of oil inlet temperature, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading that may be caused by partial arc steam admission, side streams, eccentric clearances, etc.;

c) for tilt-pad bearings, the pad pivot stiffness;

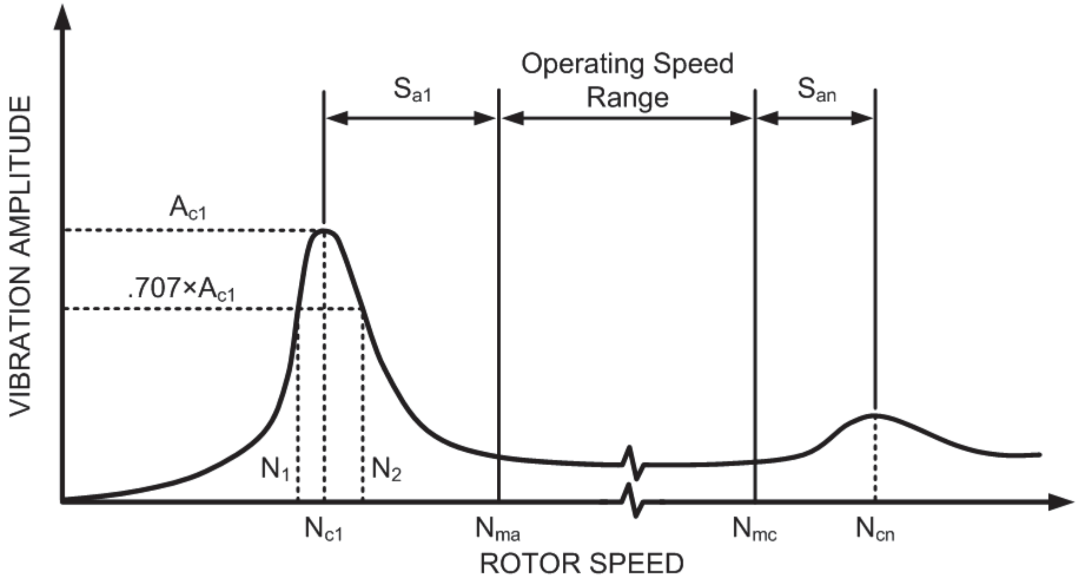
d) support stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range. The term “support” includes the foundation or support structure, the base, the machine frame, and the bearing housing as appropriate. For machines whose dynamic support stiffness values are less than or equal to 3.5 times the bearing oil film stiffness values in the range from 0 % to 150 % of N_{mc}, the support characteristics shall be incorporated as an adequate dynamic system model, calculated frequency dependent support stiffness and damping values (impedances), or support stiffness and damping values (impedances) derived from modal or other testing. 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 and support systems, or calculated support stiffness values);

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 of hydrodynamic stiffness and damping generated by the casing end seals over the operating range;

g) location and orientation of the radial vibration probes which shall be the same in the analysis as in the machine;

h) squeeze film damper mass, stiffness, and damping values considering the component clearance and centering tolerance, oil inlet temperature range, and operating eccentricity.



N_{c1} = Rotor first critical speed
N_{cn} = n^{th} critical speed
N_{ma} = Minimum allowable speed
N_{mc} = Maximum continuous speed

A_{c1} = Amplitude at N_{c1}
N_1 = Initial (lesser) speed at $0.707 \times A_{c1}$
N_2 = Final (greater) speed at $0.707 \times A_{c1}$
AF_1 = Amplification factor of the first critical speed
$= N_{c1} / (N_2 - N_1)$

S_{a1} = Actual separation between N_{c1} and the operating speed range
S_{an} = Actual separation between N_{cn} and the operating speed range
SM_{a1} = Actual separation margin of first critical speed (%)
$= 100 \times S_{a1} / N_{ma}$
SM_{an} = Actual separation margin of n^{th} critical speed (%)
$= 100 \times S_{an} / N_{mc}$

Note: The shape of the curve is for illustration only and does not necessarily represent any actual rotor response plot.

Figure 1—Rotor Response Plot

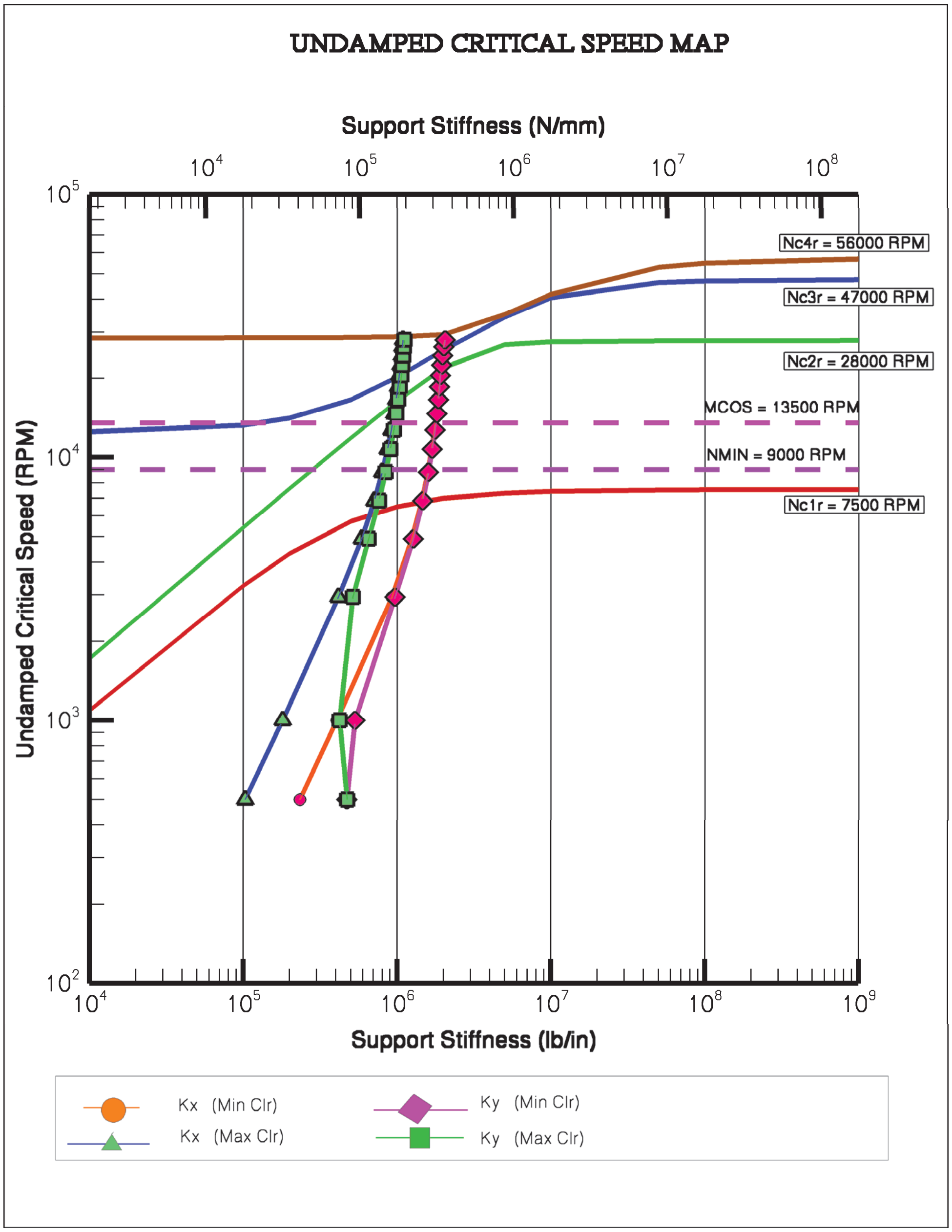


Figure 2—Undamped Critical Speed Map

● **9.2.6** If specified, the vendor with train responsibility shall provide a train lateral analysis.

9.2.7 The vendor with train responsibility shall provide a train lateral analysis for machinery trains with rigid couplings.

9.2.8 A separate damped unbalanced response analysis shall be conducted within the speed range of 0 to 1.5 N_{mc}. Unbalance shall analytically be placed at the locations defined in Figure 3 and Figure 4. For the centerline (symmetric) modes, the unbalance shall be based on the sum of the journal static loads. For conical (asymmetric) modes, unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing. For overhung modes, the unbalances shall be based on the overhung mass. Figure 3 and Figure 4 show the typical mode shapes and indicate the location and definition of U_a for each of the shapes. The magnitude of the unbalances shall be two times the value of U_r as calculated by Equation (2).

In SI units:

$$U_r = 6350 W/N_{mc} \quad (2)$$

In USC units:

$$U_r = 4 W/N_{mc}$$

where

$U_a = 2U_r$ is the input unbalance for the rotordynamic response analysis, in g-mm (oz-in.);

U_r is the maximum allowable residual unbalance, in g-mm (oz-in.);

N_{mc} maximum continuous operating speed, in r/min;

W is the journal static load 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 Figure 3 and Figure 4).

9.2.9 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 1.5 N_{mc};

b) frequency, phase and amplitude (Bode plots) at the vibration probe locations in the range from 0 to 1.5 N_{mc} resulting from the unbalances specified in 9.2.8. If there are no vibration probes near a bearing centerline, then Bode plots shall be shown at the bearing centerline;

c) plots of deflected rotor shape for each critical speed in the range from 0 to 1.5 N_{mc} and at N_{mc} resulting from the magnitudes specified in 9.2.8, showing the major-axis amplitude at the centerlines of each bearing, the locations of each radial probe, and at each seal area throughout the machine as appropriate, while, in addition, the minimum design diametral running clearance of the seals shall be indicated;

d) when the support stiffness used in the analysis is less than infinite, the Bode plots that represent the relative shaft motion and absolute bearing housing response shall be included.

9.2.10 Additional analyses shall be made for use with the verification test specified in 9.3. The location of the unbalance shall be determined by the vendor. The unbalance shall not be less than 2 times the value from Equation (2) and shall not exceed 8 times the value from Equation (2). For coupling unbalance placement (unbalance based on the overhung mass including the coupling half weight), the unbalance shall be greater than or equal to 16 times the value of Equation (2). Any test stand parameters, which influence the results of the analysis, shall be included.

NOTE There may only be one plane readily accessible for the placement of an unbalance; for example, the coupling flange on a single ended drive turbine. However, some turbines may provide additional externally accessible balance planes. When these planes exist, there exists the possibility of exciting other critical speeds; multiple runs may be required.

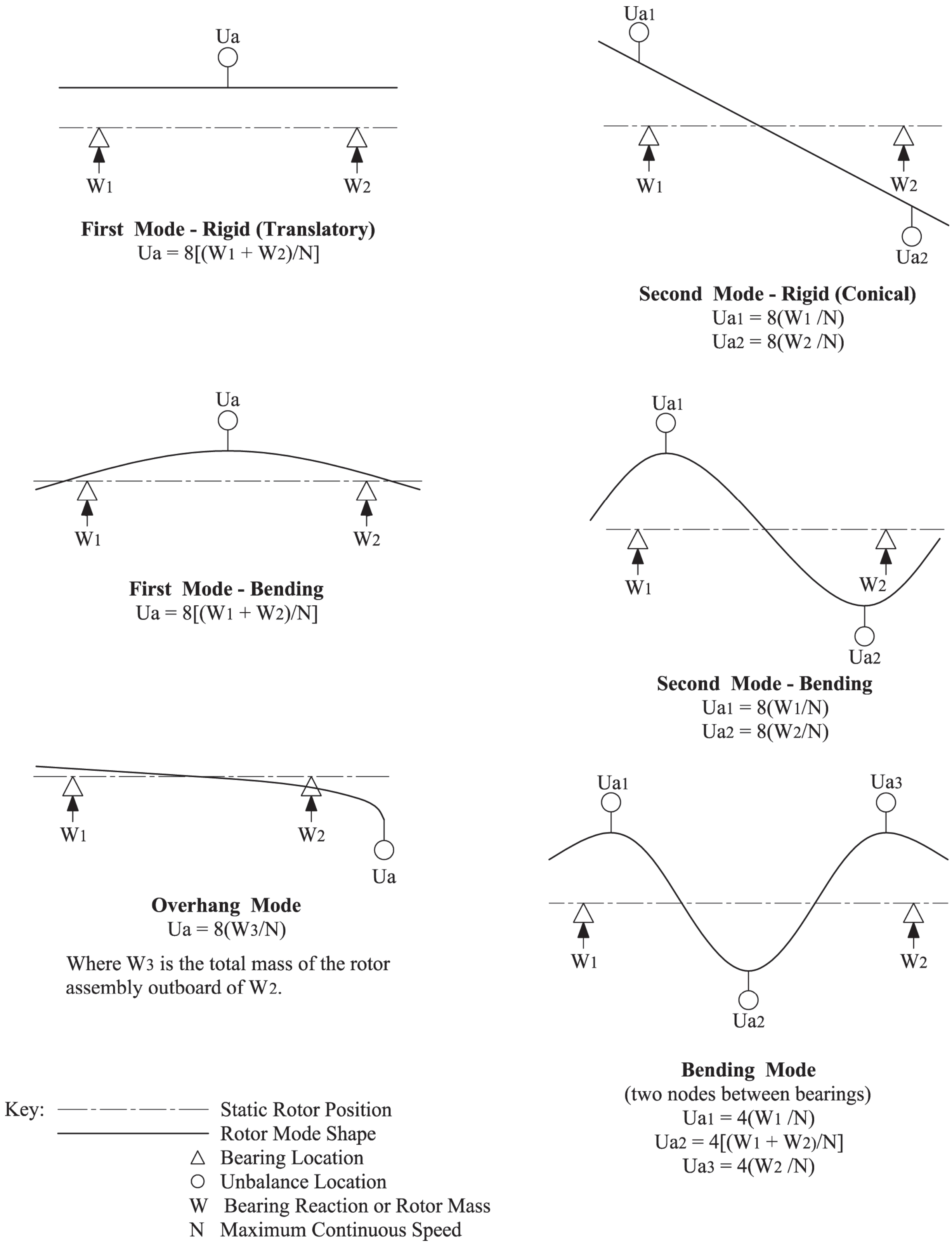


Figure 3—Typical Mode Shapes—Most Mass Between Bearings

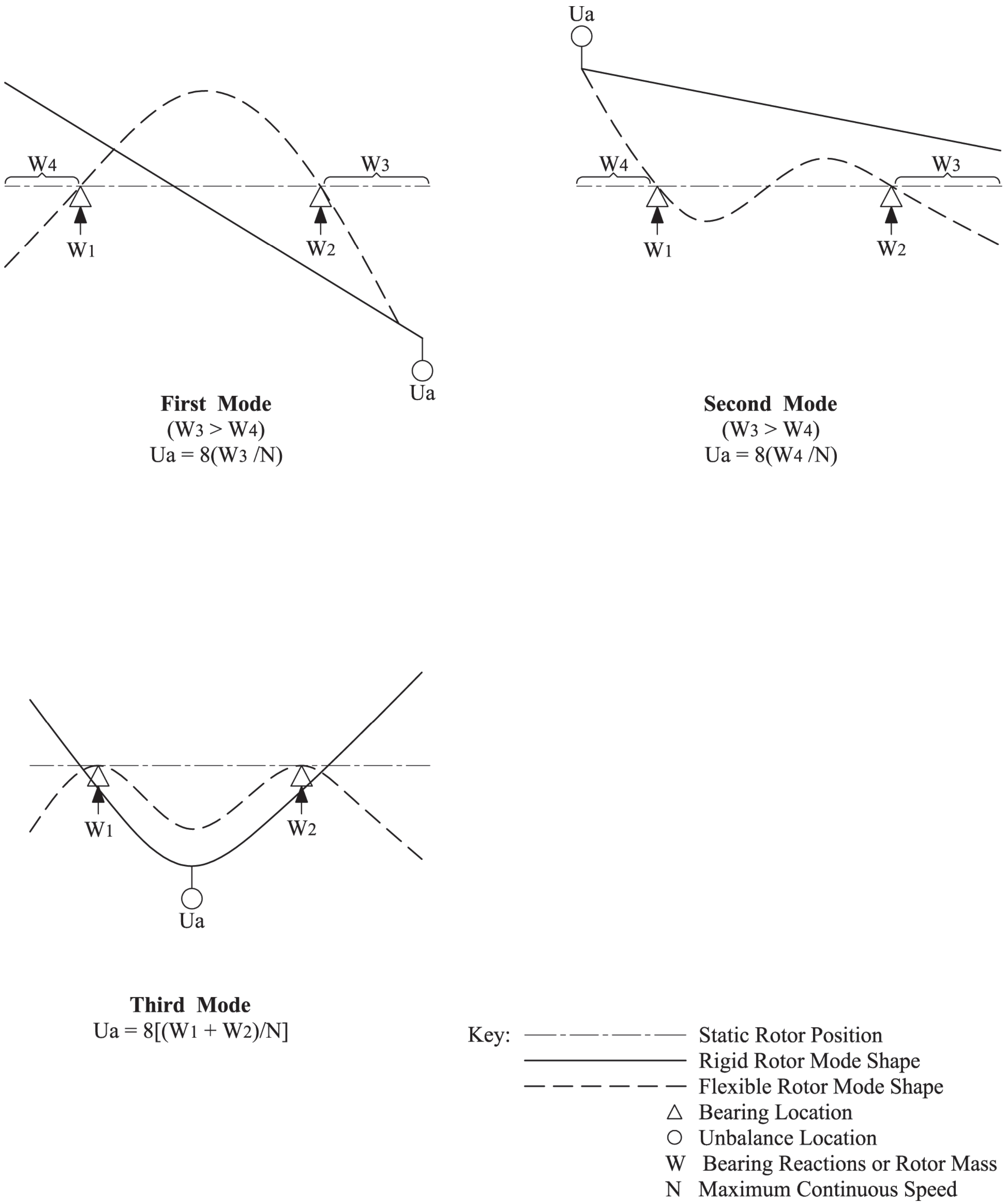


Figure 4—Typical Mode Shapes—Most Mass Outboard of Bearings

9.2.11 The damped unbalanced response analysis shall indicate that the machine will meet the following requirement:

$$M_{sa} \geq M_{sr}$$

where

M_{sr} is the required separation margin in %;

M_{sa} is the actual separation margin in %.

If the amplification factor at a particular critical speed is less than 2.5, the response is considered critically damped and no separation margin is required (M_{sr} = 0).

a) If the amplification factor at a particular critical speed is greater than or equal to 2.5 and that critical speed is below the minimum allowable speed, M_{sr} is given by Equation (3).

$$M_{sr} = 17\left(1 - \frac{1}{F_a - 1.5}\right) \quad (3)$$

b) If the amplification factor at a particular critical speed is greater than or equal to 2.5 and that critical speed is above the maximum continuous speed, M_{sr} is given by Equation (4).

$$M_{sr} = 10 + 17\left(1 - \frac{1}{F_a - 1.5}\right) \quad (4)$$

c) If the particular critical speed is in the operating speed range (N_{ma} to N_{mc}) and the amplification factor is greater than or equal to 2.5, then it does not meet the requirements.

9.2.12 The calculated unbalanced peak-to-peak response at each vibration probe, for each unbalance amount and case as specified in 9.2.9, shall not exceed the mechanical test vibration limit of 25.4 μm (1.0 mil) or Equation (5), whichever is less, over the range of N_{ma} to N_{mc} as shown in Figure 5.

In SI units:

$$A_1 = 25.4\sqrt{\frac{12,000}{N}} \quad (5)$$

In USC units:

$$A_1 = \sqrt{\frac{12,000}{N}}$$

where

$N = N_{mc}$.

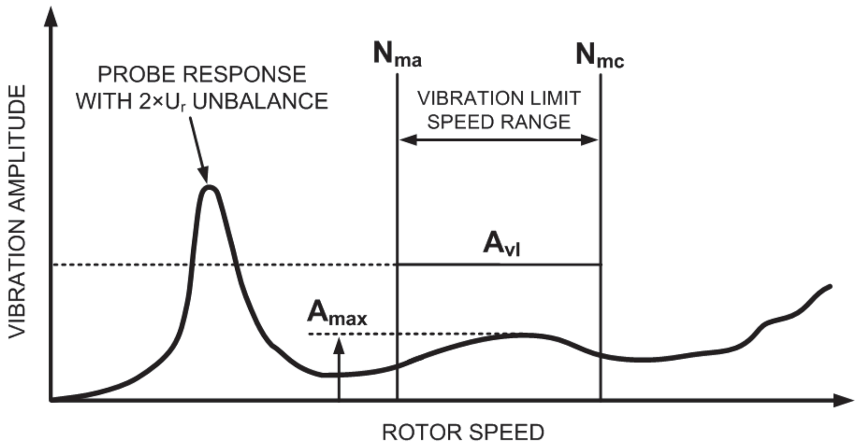


Figure 5—Vibration Limits

9.2.13 The following shall apply.

a) For each unbalance amount and case as specified in 9.2.8, the calculated major-axis, peak-to-peak response at each close clearance location shall be multiplied by a scale factor defined by Equation (6). To meet the requirements of 9.2.12, the scale factor shall be greater than one.

$$S_{cc} = A_{vl}/A_{max} \text{ or 6, whichever is less} \tag{6}$$

where

S_{cc} is the scale factor for close clearance check;

A_{vl} is the mechanical test vibration limit defined in 9.2.12;

A_{max} is the maximum probe response amplitude (p-p) considering all vibration probes, over the range of N_{ma} to N_{mc}, for the unbalance amount/case being considered.

b) For each close clearance location, the scaled response shall be less than 75 % of the minimum design diametral running clearance over the range from zero to trip speed.

c) For this evaluation, floating-ring, abradable, and compliant seals are not considered to be close clearance locations. The response amplitude to the running clearance at these locations shall be mutually agreed.

d) Running clearances may be different than the assembled clearances with the machine shutdown. Consideration should be given to:

1) centrifugal/thermal growth,

2) bearing lift,

3) rotor sag,

4) nonconcentricity (of stator to the bearings).

9.2.14 If the analysis indicates that:

— the required separation margins as given in 9.2.11 cannot be met; or

— the vibration limit requirements of 9.2.12 are not met; or

— the clearance requirements of 9.2.13 are not met; and

— the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes and amplification factors shall be agreed upon by the purchaser and the vendor, subject to the requirements of 9.5.

9.3 Stability Analysis

9.3.1 A stability analysis shall be performed on all rotors except those whose maximum continuous speed is below the first undamped critical speed on rigid supports in accordance with 9.2.3. A stability analysis shall be performed on all rotors with fixed geometry bearings. The stability analysis shall be calculated at the maximum continuous speed.

9.3.2 The stability analysis shall identify the first forward whirl damped natural frequency and corresponding logarithmic decrement of the rotor, bearing, and support system when operating at N_{mc}.

9.3.3 Level I Stability Analysis

● **9.3.3.1** If specified, a Level I stability analysis shall be conducted in accordance with 9.3.3.1 through 9.3.3.9. For this analysis, the turbine steam conditions, power, and speed shall be at the rated condition unless the vendor and purchaser agree upon another operating point.

NOTE Level I analysis was developed to fulfill two purposes: first, it provides an initial screening to identify rotors that do not require a more detailed study. The approach as developed is conservative and not intended as an indication of an unstable rotor. Second, the Level I analysis specifies a standardized procedure applied to all manufacturers. API 684 provides further information on rotordynamics.

9.3.3.2 The model used in the Level I analysis shall include the items listed in 9.2.5.

9.3.3.3 If tilting pad journal bearings are used, the analysis shall be performed with synchronous tilting pad coefficients.

9.3.3.4 For rotors that have quantifiable external radial loading (including partial admission steam forces), the stability analysis shall also include the external loads associated with the operating conditions defined in 9.3.3.1. For some rotors, the unloaded (or minimal load condition) may represent the worst stability case and should be considered.

9.3.3.5 The anticipated cross coupling, Q_{A}, present in the rotor shall be calculated using the following equation:

For axial flow rotors:

$$q_{\mathrm{a}} = \frac{PB_{\mathrm{t}}C}{D_{\mathrm{t}}H_{\mathrm{t}}N_{\mathrm{r}}} \tag{7}$$

Equation (7) is calculated for each stage of the rotor. Q_{A} is equal to the sum of q_{A} for all stages. Equation variables are defined in 9.3.4.9.

9.3.3.6 An analysis shall be performed with a varying amount of cross coupling introduced at the rotor mid-span for between-bearing rotors or at the center of gravity of the wheel for single overhung rotors. For double-overhung rotors, the cross coupling shall be placed at each wheel concurrently and should reflect the ratio of the anticipated cross coupling, q_{A}, calculated for each stage.

9.3.3.7 The applied cross coupling shall extend from zero to the lesser of:

a) a level equal to 10 times the anticipated cross coupling, Q_A;

b) the amount of the applied cross coupling required to produce a zero log decrement, Q_0. This value can be reached by extrapolation or linear interpolation between two adjacent points on the curve.

9.3.3.8 A plot of the calculated log decrement, δ, for the first forward mode shall be prepared for the minimum and maximum component stiffness as defined in 9.2.5 b), 9.2.5 f), and 9.2.5 h). The ordinate (y-axis) shall be the log decrement. The abscissa (x-axis) shall be the applied cross coupling with the range defined in 9.3.3.7. For double-overhung rotors, the applied cross coupling shall be the sum of the cross coupling applied to each wheel.

NOTE A typical plot is presented in Figure 6. Q_0 and δ_A are identified as the minimum values from either component clearance curves.

9.3.3.9 Level I Screening Criteria for axial flow rotors:

If δ_A < 0.1, a Level II stability analysis shall be performed. Otherwise, the stability is acceptable and no further analyses are required.

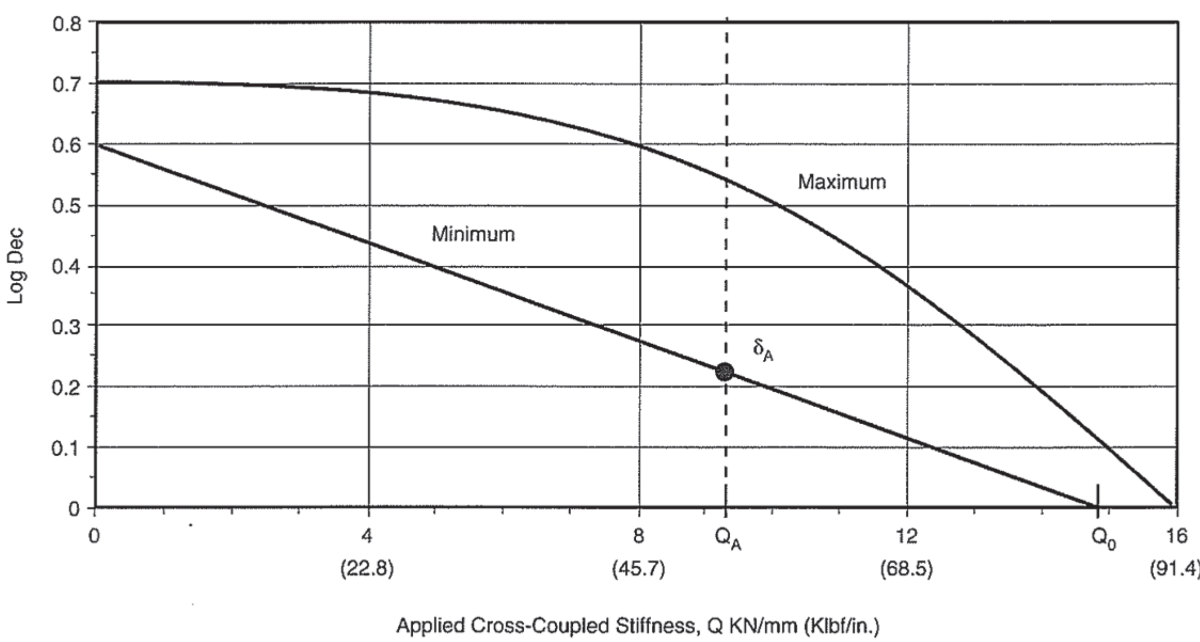


Figure 6—Typical Plot of Log Decrement vs Component Stiffness

9.3.4 Level II Stability Analysis

9.3.4.1 A Level II analysis, which reflects the actual dynamic forces (both stabilizing and destabilizing) of the rotor, shall only be performed if required by 9.3.3.9.

9.3.4.2 The Level II analysis shall include the dynamic effects from all sources that contribute to the overall stability of the rotating assembly. These dynamic effects shall replace the anticipated cross coupling, Q_A. The following sources shall be included in the analysis:

a) labyrinth seals,

b) damper seals,

c) blade flow aerodynamic effects,

d) internal friction.

The vendor shall state how the sources are handled in the analysis.

NOTE It is recognized that methods might not be available at present to accurately model the destabilizing effects from all the sources listed above.

9.3.4.3 The Level II analysis shall be calculated at N_{mc}.

9.3.4.4 The modeling requirements of Level I shall also apply.

9.3.4.5 The dynamic coefficients of the labyrinth seals shall be calculated at minimum seal running clearance.

9.3.4.6 The frequency and log decrement of the first forward damped mode shall be calculated for the following configurations (except for double-overhung machines, where the first two forward modes shall be considered):

a) rotor and support system only (basic log decrement, δ_b);

b) each source from 9.3.4.2 utilized in the analysis;

c) complete model including all sources (final log decrement, δ_f).

9.3.4.7 The Level II stability analysis shall indicate that the machine, as calculated in 9.3.4.1 through 9.3.4.6, shall have a final log decrement, δ_f, greater than 0.1.

9.3.4.8 If after all practical design efforts have been exhausted to achieve the requirements of 9.3.4.7, acceptable levels of the log decrement, δ_f, shall be agreed upon by the purchaser and vendor.

The historical data accumulated by machinery manufacturers for successfully operated machines may conflict with the acceptance criteria of 9.3.4.5. If such a conflict exists and the vendors can demonstrate that their stability analysis methods and acceptance criteria predict a stable rotor, then the vendor’s’ criteria should be the guiding principle in the determination of acceptability.

9.3.4.9 The following symbols apply:

B_t equals 1.5

C equals 9.55 (63)

D_t is the blade pitch diameter, in mm (in.)

H_t is the effective blade height, in mm (in.)

P is the rated power per stage, in W (hp)

N is the operating speed, in r/min

Q_A is the anticipated cross coupling for the rotor, kN/mm (klbf/in.) defined as:

$$Q_A = \sum_{i=1}^{S} q_{Ai} \tag{8}$$

Q_0 is the minimum cross-coupling needed to achieve a log decrement equal to zero for either minimum or maximum component clearance, in kN/mm (klbf/in.)

q_a is the cross coupling defined in Equation (7) for each stage or impeller, in kN/mm (klbf/in.)

S is the number of stages

δ_A is the minimum log decrement at the anticipated cross coupling for either minimum or maximum component clearance

δ_b is the basic log decrement of the rotor and support system only

δ_f is the log decrement of the complete rotor and support system from the Level II analysis

9.3.4.10 Maximum preload for a tilt pad bearing occurs at the minimum clearance condition. The maximum preload can be calculated using the following formulas:

$$m_{max} = 1 - \left(\frac{c_{bmin}}{r_{pmax} - r_{smax}} \right) \tag{9}$$

$$c_{bmin} = r_{bmin} - r_{smax} \tag{10}$$

where

m_{max} is the maximum bearing preload;

c_{bmin} is the minimum bearing clearance;

r_{pmax} is the maximum pad radius;

r_{smax} is the maximum shaft radius;

r_{bmin} is the minimum bearing radius.

9.3.4.11 Minimum preload for a tilt pad bearing occurs at the maximum clearance condition. These can be calculated using the following formulas:

$$m_{min} = 1 - \left(\frac{c_{bmax}}{r_{pmin} - r_{smin}} \right) \tag{11}$$

$$c_{\text{bmax}} = r_{\text{bmax}} - r_{\text{smin}} \tag{12}$$

where

m_{min} is the minimum bearing preload;

c_{bmax} is the maximum bearing clearance;

r_{pmin} is the minimum pad radius;

r_{smin} is the minimum shaft radius;

r_{bmax} is the maximum bearing radius.

9.4 Unbalanced Rotor Response Verification Test

9.4.1 An unbalanced rotor response test shall be performed as part of the mechanical running test (see 16.3.3), 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 9.2.11 shall be used for determining the validity of the damped unbalanced response analysis. To accomplish this, the requirements of 9.4.1.1 through 9.4.1.6 shall be met.

9.4.1.1 During the mechanical running test (see 16.3.3), the amplitudes and phase angle of the shaft vibration from trip to slow roll speed shall be recorded after the four-hour run. The recording instrumentation resolution shall be at least 1.25 µm (0.05 mils).

NOTE This set of readings is normally taken during coast-down, with convenient increments of speed such as 50 r/min. Since the rotor is fully balanced at this point, any vibration amplitude and phase detected is usually the result of residual unbalance and mechanical and electrical runout.

9.4.1.2 The unbalance, which was used in the analysis performed in 9.2.11, shall be added to the rotor in the location used in the analysis.

9.4.1.3 The machine shall then be brought up to N_{mc} and held for at least 15 minutes and then brought up to trip speed and the indicated vibration amplitudes and phase shall be recorded using the same procedure used for 9.4.1.1 during the coast-down.

9.4.1.4 The location of critical speeds below the trip speed shall be established. If a clearly defined response peak is not observed during the test, then the critical speeds shall be identified as those in the rotordynamic report.

NOTE Slow roll runout should be vectorially subtracted from the 1X Bode plots to accurately define the location of the critical speeds.

9.4.1.5 The corresponding indicated vibration data taken in accordance with 9.4.1.1 and 9.4.1.3 shall be vectorially subtracted. The slow roll runout shall be checked prior to subtraction. This should be nearly identical for both runs.

9.4.1.6 The results of the mechanical run, including the unbalance response verification test, shall be compared with those from the analytical model specified in 9.2.11. The probe orientation shall be the same for the analysis and the machine. Otherwise, the comparison is invalid.

9.4.2 Using the unbalance response test results, the vendor shall correct the model if it fails to meet either of the following criteria.

a) The actual critical speed ranges determined on test shall not deviate from the corresponding critical speed ranges predicted by analysis by more than ±5 %.

b) The maximum probe responses in the range zero to trip speed from the results of 9.4.1.5 shall not exceed the predicted ranges from 9.2.11.

9.4.3 The vendor shall determine whether the comparison will be made for absolute or relative motion. For absolute motion, bearing housing vibration shall be added to relative probe readings. This shall be the case for machinery with soft supports.

9.4.4 Unless otherwise specified, the verification test of the rotor unbalance shall be performed only on the first rotor tested, if multiple identical rotors are purchased.

9.4.5 After correcting the model, if required, analytical response amplitudes shall be checked against the limits specified in 9.2.13 and 9.2.14 and the analytical critical speed separation margins shall be checked against the requirements of 9.2.12.

9.5 Additional Testing

9.5.1 Additional testing is required if, from the shop verification test data (see 9.4) or from the damped unbalanced response analysis, either of the following conditions exists:

a) any critical speed fails to meet the M_{sr} requirements of 9.2.11,

b) the vibration limit requirements of 9.2.12 have not been met,

c) the clearance requirements of 9.2.13 have not been met.

If the analysis or test data does not meet the requirements of this standard, additional more stringent testing shall be performed to determine on the test stand that the machine will operate successfully in practice.

9.5.2 Unbalance weights shall be placed as described in 9.2.10; 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 as defined in 9.2.12 at the maximum continuous speed; however, the unbalance used shall be not less than twice and not greater than eight times the unbalance limit specified in 9.2.8, Equation (2). The measurements from this test, taken in accordance with 9.4.1.1 and 9.4.1.3 shall meet the following criteria:

a) from zero to trip speed, the shaft deflections shall not exceed 90 % of the minimum design running clearances;

b) within the operating speed range, including the M_{sr}, the shaft deflections shall not exceed 55 % of the minimum design running clearances or 150 % of the allowable vibration limit at the probes (see 9.2.12 and 9.2.13);

c) for this evaluation, floating-ring, abradable, and compliant seals are not considered to be close clearance locations. Acceptable response amplitude at these locations shall be mutually agreed upon.

9.5.3 The internal deflection limits specified in 9.5.2 a) through 9.5.2 c) shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 9.2.13, based on a corrected model, if required. Acceptance will be based on these calculated displacements or inspection of the seals if the machine is opened.

NOTE Internal displacements for these tests are calculated by multiplying these ratios by the peak readings from the probes.

9.5.4 Damage to any portion of the machine as a result of this testing shall constitute failure of the test. Internal seal rubs that do not cause clearance or geometry changes outside the vendor's new-part tolerances do not constitute damage.

9.6 Torsional Analysis

9.6.1 The vendor having unit responsibility shall ensure that a torsional vibration analysis of the complete coupled train is performed and shall be responsible for directing any modifications necessary to meet the requirements of 9.6.2 to 9.6.6.

9.6.2 Excitation of torsional natural frequencies can come from many sources, which might or might not be a function of running speed and should be considered in the analysis. The sources to be considered shall include at least the following:

a) gear characteristics such as mesh frequency unbalance, pitchline runout, and cumulative pitch error;

b) cyclic process impulses;

c) running speed or speeds;

d) torsional pulsations due to gear radial vibrations;

e) torsional excitation resulting from reciprocating and rotary type positive displacement machines.

9.6.2.1 If motors or generators are part of the train, torsional excitation sources to be considered shall also include at least the following:

a) torsional transients such as start-up of synchronous electric motors and generator phase-to-phase or phase-to-ground faults;

b) torsional excitation resulting from electric motors;

c) one or two times line frequency;

d) harmonic frequencies from variable frequency drivers when motor drivers are part of the drive train.

9.6.3 Interferences of the primary (coupling) modes and 1X excitation frequency (mechanical or electrical) shall be at least 10 % above or 10 % below the specified operating speed range.

9.6.4 All other interferences with torsional natural frequencies and any possible excitation frequency shall preferably be at least 10 % above or 10 % below the specified operating speed range (from minimum to maximum continuous speed).

9.6.4.1 Any interference resulting from 9.6.4 shall be shown to have no adverse effect using 9.6.5.

9.6.5 When torsional resonances are calculated to fall within the margin specified in 9.6.4 (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 steady state stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train.

9.6.6 In addition to the torsional analysis required in 9.6.2 and 9.6.5, the vendor shall perform a transient torsional vibration analysis when synchronous motor or generator drives are part of the train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and vendor.

The analysis shall generate the maximum torque as well as a torque versus time history for each of the shafts in the machinery train. The maximum torques shall be used to evaluate the peak torque capability of coupling components, gearing, and interference fits of components such as coupling hubs. Appropriate fatigue properties and stress concentrations shall be used.

9.7 Vibration and Balancing

9.7.1 Major parts of the rotating element, such as the shaft, balancing drum, and discs, shall be individually dynamically balanced before assembly to ISO 1940 Grade G0.67 or better. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key in accordance with ISO 8821. Keyways 180° apart, but not in the same transverse plane, shall be filled. The initial balance correction to the bare shaft shall be recorded. The components to be mounted on the shaft (balance drum, disc, etc.) shall be balanced in accordance with the "half-key-convention" as described in ISO 8821.

9.7.2 The rotating element shall be sequentially multiplane dynamically balanced during assembly. This shall be accomplished after the addition of no more than two major components, except on integral disc rotating elements. Balancing correction shall only be applied to the elements added. Minor correction of other components may be required during the final trim balancing of the completely assembled element. In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 9.7.1) shall continue to be used until they are replaced with the final key and mating element. On rotors with single keyways, the keyway shall be filled with a fully crowned half-key. The mass of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance worksheet (see Annex C). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units:

$$U_{\text{max}} = \frac{6350 \times m}{n} \qquad (13)$$

In USC units:

$$U_{\text{max}} = \frac{4 \times m}{n}$$

where

U_{max} is the residual unbalance in gram-millimeters (ounce-inches);

m is the journal static mass, in kilograms (pounds);

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

9.7.3 A rotor that has been low-speed balanced (see 9.7.2) shall have a low-speed residual unbalance check performed in a low-speed balance machine in accordance with Annex C and recorded on the residual unbalance worksheet.

NOTE This procedure provides a reference of residual unbalance and phase for future use in a low-speed balance machine.

● **9.7.4** If specified, the completely assembled rotating element shall be operating speed balanced after low speed sequential balancing (see 9.7.2). The operating speed balance shall be in accordance with 9.7.5, 9.7.6, and 9.7.7.

9.7.5 Operating Speed Balancing Procedure

9.7.5.1 The following information shall be available for review prior to operating speed balancing:

a) the contract rotordynamics analysis (this analysis shall provide information about the predicted rotor mode shape as it passes through its resonant frequencies and about the best location for balance weights to minimize rotor vibration);

b) final low speed balance records;

c) mechanical radial and axial runout checks of the rotor straightness;

d) if applicable, transfer tapes showing contact-hydraulic fit coupling hub/shaft end;

e) job bearing details.

9.7.5.2 During operating speed balancing, it is preferable to use the actual job bearings or bearings of the same type and with similar dynamic characteristics to the job bearings. With the approval of the purchaser, operating speed balance stand bearings may be used. If job bearings are not used, operating speed balancing bearings coefficients shall be determined. The turbine manufacturer shall determine the dynamic operating characteristics of the rotating element with the operating speed balance bearings and pedestal dynamic properties, and the balance facility drive coupling. This data shall be provided in addition to that required in 9.7.5.1 a).

NOTE Evacuated tilting pad bearings (bearings without end seals) may require temporary end seals with about twice the bearing clearance. Inlet oil is typically supplied to the bearing housing near 138 kPa (20 psig), but the housing cannot maintain a positive pressure and the oil immediately atomizes, resulting in oil starvation. This may manifest itself as a subsynchronous rotor vibration.

9.7.5.3 The rotor shall be completely assembled prior to operating speed balancing including thrust collars, locking collars, power take-off gears, overspeed trip assemblies, speed sensing rings for governor and overspeed devices, etc.

9.7.5.4 The balancing facility's drive coupling shall be attached to the rotor via a plate bolted to the end of the shaft. This attachment shall be arranged to minimize any unbalance due to eccentricity. In some cases, the job-coupling hub with moment simulator may be required to simulate the rotordynamics, especially for the outboard ends of drive-through machines.

● **9.7.5.5** If specified, in addition to the normal velocity sensors at each bearing pedestal, two orthogonally mounted radial noncontacting vibration probes shall be mounted in line with the prepared probe shaft sensing area near each journal bearing and at mid shaft. All probes shall be at the same circumferential orientation.

9.7.5.5.1 If noncontacting vibration probes have been specified, structural resonance frequency of the probes and supports shall be determined after installation of the rotor and probe assemblies in the balance facility.

9.7.5.6 The balance facility bearing pedestal selection shall best represent the combined dynamic properties of the turbine journal bearing and bearing supports.

9.7.5.7 Adjust lube oil temperature to simulate normal operating viscosity.

9.7.5.8 Prior to operating speed balancing, the complete rotor shall be balance checked at a speed below the rotor's first critical speed in the operating speed balancing facility. If the measured unbalance exceeds five times the residual unbalance limit, the sequential multiplane dynamic balance and runout records from 9.7.2 shall be reviewed and the cause for the unbalance determined.

NOTE The purpose of minimizing the unbalance is to increase the possibility of the rotor successfully transversing its critical speed(s) and reaching operating speed.

9.7.5.9 Prior to balancing, the rotor residual unbalance shall be stabilized. This shall be accomplished by the following.

a) Record slowroll (500 r/min to 800 r/min) residual unbalance (amount and phase) before running up in speed.

b) Run the rotor to trip speed and hold for 3 min. Reduce the speed to N_{mc} and record the residual unbalance and phase angle on each pedestal.

c) Reduce the speed to between 500 r/min and 800 r/min and record slow roll data again.

d) Repeat until slow roll and N_{mc} residual unbalance and phase angles are consistent.

9.7.5.10 Rotate the drive shaft and any drive shaft adaptor plate 180°. Unbalance shall not change by more than 0.0005 times the half-weight of the coupling and adaptor. If approved by the purchaser, calculation algorithms for correcting the balancing results may be applied to the final rotor balance.

9.7.5.11 Permanent balance corrections shall be made per 9.7.5.11.1, 9.7.5.11.2, 9.7.5.11.3, and 9.7.5.11.4 as applicable. These corrections shall be accomplished by adding balancing weights, grinding, or both of these methods.

9.7.5.11.1 Field accessible balance provisions shall not be used for balance corrections.

9.7.5.11.2 If grinding is necessary, grind in the plane where the trial weight was removed. If necessary, blend the correction grind to prevent stress risers.

9.7.5.11.3 If the turbine vendor specifies that balance corrections will be made on the disks by grinding, grinding shall occur on the disk in the region dedicated for balance correction as defined by the turbine manufacturer. If necessary, the correction grind shall be blended to prevent stress risers and spread out to limit thinning of the disk material. Balance corrections on any other area of the disk are not permitted without the approval of the turbine manufacturer.

9.7.5.11.4 If the turbine vendor specifies that balance corrections will be made on the disks by adding weights, the weights shall be specifically designed for each disk and shall be placed in the designated balance groove. Balance weights shall be compatible with the disk material and suitable for the operating environment. Balance corrections on any other area of the disk are not permitted without the approval of the turbine manufacture.

9.7.5.12 After the rotor is balanced within the tolerances of 9.7.6, repeat the final balance run with increased pedestal stiffness (if possible). Rotor balance with increased pedestal stiffness shall be in accordance with 9.7.6

9.7.5.13 After permanent operating speed balance corrections are made, a residual unbalance check shall be performed in a low-speed balancing machine in accordance with Annex C and recorded on the residual unbalance worksheet.

NOTE This is done to provide a reference for residual unbalance and phase if the rotor is checked in the future using a low speed balance machine.

9.7.6 Unless otherwise specified, the vibration acceptance criteria for operating-speed balancing, with pedestal stiffness in accordance with 9.7.5.6, measured on or near the bearing pedestals, shall be that specified in 9.7.6.1 or 9.7.6.2, whichever is less, and 9.7.6.3.

9.7.6.1 For all speeds at or less than 3000 r/min, the pedestal vibration shall not exceed 2.5 mm/s (0.098 in./s) RMS. For speeds above 3000 r/min, the pedestal vibration shall not exceed the calculated value of (7400/N) mm/s [(291/N) in./s] or 1 mm/s (0.039 in./s) RMS, whichever is the greater, where N is the speed in r/min up to N_{mc}.

9.7.6.2 For all speeds up to N_{mc}, the pedestal vibration shall not exceed the following:

In SI units:

$$\text{Velocity, mm/s RMS} = 74 \times 0.2 \times W \times N / K \tag{14}$$

where

0.2 is the g force on the pedestals;

W is the bearing reaction, in N;

N is the speed, in r/min;

K is the pedestal stiffness, in N/m.

In USC units:

$$\text{Velocity, in./s RMS} = 0.074 \times 0.2 \times W \times N / K$$

where

0.2 is the g force on the pedestals;

W is the bearing reaction, in lbf;

N is the speed, in r/min;

K is the pedestal stiffness, in lbf/in.

9.7.6.3 When noncontacting vibration probes have been specified in 9.7.5.5, the maximum allowable shaft vibration (1X filtered and runout compensated) shall not exceed 1.0 mil peak-to-peak at any response or 0.5 mil peak-to-peak over operating speed range for probes near the bearings.

9.7.7 Upon completion of operating speed balancing the following data shall be provided for the initial run to operating speed, the stabilized rotor prior to balancing, and for the final balanced rotor, including any effects of pedestal stiffness variations:

a) Bode and polar plots for each pedestal velocity probe;

b) when proximity probes have been specified: Bode, cascade, polar, eccentricity (shaft centerline), and filtered (1X) shaft orbital plots of each proximity probe for coast-down (without speed detents). Proximity probe data shall be compensated for slow roll mechanical and electrical runout;

c) spectrum (amplitude vs frequency) plots of rotor at N_{mc}.

9.7.8 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 (including runout) of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 25.4 µm (1.0 mil), whichever is less.

In SI units:

$$A_1 = 25.4\sqrt{\frac{12{,}000}{N}} \tag{15}$$

In USC units:

$$A_1 = \sqrt{\frac{12{,}000}{N}}$$

where

A is the amplitude of unfiltered vibration, expressed in µm (mil) peak to peak;

$N = N_{mc}$ is the maximum continuous speed, expressed in revolutions per minute.

At any speed greater than N_{mc}, up to and including the trip speed, the vibration level measured by any probe shall not exceed the sum of 13 µm (0.5 mil) and the peak-to-peak amplitude of unfiltered vibration detected by that probe at the maximum continuous speed.

Warning—Do not confuse these limits with the limits specified in 9.4 for shop verification of unbalanced response.

. **9.7.9** Electrical and mechanical runout shall be determined by rotating the rotor throughout the full 360° supported in V blocks at the journal centers while measuring runout with a noncontacting vibration probe and a dial indicator at the centerline of each probe location and one probe-tip diameter to either side.

9.7.10 Accurate records of electrical and mechanical runout, for the full 360° at each probe location, shall be included in the mechanical test report.

10 Bearings Bearing Housings, and Seals

10.1 Bearings—General

● **10.1.1** If specified, active magnetic bearings shall be provided, otherwise hydrodynamic radial and thrust bearings shall be provided.

10.1.1.1 Detailed design of active magnetic bearings shall be mutually agreed between the steam turbine vendor and the purchaser.

10.1.2 Hydrodynamic thrust and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670.

10.1.3 Thrust bearing and radial bearing designs shall be:

a) suitable for operating at barring and turning gear speeds without damaging the Babbitt lining,

b) designed for reverse rotation for short durations without damaging the Babbitt lining for mechanical drive application.

● **10.1.3.1** If specified, thrust and radial bearings shall be capable of reverse rotation operating conditions defined by the purchaser.

10.2 Radial Bearings

10.2.1 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and sleeved or padded, with steel-backed, Babbitted replaceable liners, pads, or shells. These bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction. The liners, pads, or shells shall be in axially split housings and shall be replaceable without the removal of the top half of the casing of an axially split machine or the head of a radially split unit and without the removal of the coupling hub.

10.2.2 Radial bearing design shall be such that load transfer to the bearing housing by the bearing shall not cause damage to critical bearing housing surfaces that are not considered normal wearing surfaces subject to repair or replacement.

10.2.3 Radial bearings shall be designed to prevent incorrect positioning.

● **10.2.4** If specified, radial bearing pads shall be copper-alloy backed and shall have hardened steel inserts for support.

10.3 Thrust Bearings and Collars

10.3.1 Thrust bearings shall be hydrodynamic and steel-backed, with Babbitted multiple segments, designed for equal thrust capacity in both directions, and arranged for continuous pressurized lubrication to each side. Tilting pads shall be used on both sides and shall incorporate a self-leveling feature ensuring that each pad carries an equal share of the thrust load with minor variations in pad thickness.

10.3.2 Thrust bearings shall be sized for continuous operation 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 up to twice the design internal clearances;

b) step thrust from all diameter changes;

c) stage reaction and stage differential pressure;

d) variations in inlet, extraction, induction, and exhaust pressure;

e) external loads from the driven equipment in accordance with 10.3.3 and 10.3.4.

10.3.3 External loads transmitted through flexible-element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

10.3.4 If two or more rotor thrust forces are to be carried by one thrust bearing, 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.

10.3.5 Thrust bearings shall be selected at no more than 50 % of the bearing manufacturer's ultimate load rating. The ultimate load rating is the load that produces the minimum acceptable oil film thickness without inducing failure during continuous service or the load that does not exceed the creep-initiation or yield strength of the Babbitt at the maximum temperature location on the pad, whichever load is less. In sizing thrust bearings, consideration shall be given to, but shall not be limited 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;

h) the pad material;

i) the turbulence of the oil film.

The basis for sizing of thrust bearings shall be made available for review by the purchaser.

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

10.3.7 Unless otherwise specified, integral thrust collars shall be furnished. They shall be provided with at least 3 mm ($^1/_8$ in.) of additional stock on total thickness to enable refinishing if the collar is damaged. When replaceable collars are furnished, they shall be shrunk on, and positively locked to, the shaft to prevent fretting.

10.3.8 Both faces of thrust collars shall be finished to a surface roughness not exceeding 0.8 µm (32 µin.) Ra. The axial total indicated runout of either face shall not exceed 13 µm (0.0005 in.).

10.3.9 If specified, thrust bearing pads shall be copper-alloy backed and shall have hardened steel inserts for support.

10.4 Bearing Housing

10.4.1 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. The rise in oil temperature through the bearing and housings shall not exceed 30 °C (50 °F) under the most adverse specified operating conditions. The bearing outlet oil temperature shall not exceed 80 °C (180 °F). When the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow, and allowable temperature rise. Oil outlets from flooded thrust bearings shall be tangential and in the upper half of the control ring or, if control rings are not used, in the thrust-bearing cartridge.

10.4.2 Bearing housings shall be equipped with replaceable labyrinth end seals and deflectors where the shaft passes through the housing; lip-type end seals shall not be used. The seals and deflectors shall be made of nonsparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

10.4.3 Cantilevered shaft support structures bolted to steel casings shall be steel.

10.4.4 Cast iron bearing housings or bearing housing supports shall not be used.

10.4.5 Provision shall be made for mounting two noncontacting radial-vibration probes in each bearing housing, two axial-position probes at the thrust end of each machine, and a one-event-per-revolution probe in each machine. Probe installation shall be as specified in API 670.

● **10.4.6** If specified, provisions for mounting accelerometers on the bearing housings shall be made in accordance with API 670.

10.4.7 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.

10.4.8 Bearing housings shall be axially split and shall have a metal-to-metal joint with cylindrical locating dowels.

10.5 Grounding

Unless otherwise specified, condensing turbines shall be provided with at least two grounding brushes on the same end of the shaft. Unless otherwise specified, the arrangement of the brushes shall be designed to enable the brushes to be replaced with the turbine in operation. The brushes shall be a standard size and grade suitable for the service. The vendor shall include drawings with the proposal showing the number and location of the brushes.

10.6 Shaft Seals

10.6.1 Unless otherwise specified, casing end seals shall be replaceable labyrinth seals, brush seals, or a combination of both.

10.6.2 Interstage sealing shall be by replaceable labyrinths, brush seals, or a combination of both.

10.6.3 Labyrinth casing end seals operating at less than atmospheric pressure shall be designed for admission of dry steam to seal against air ingress.

10.6.3.1 Piping with pressure gauges, regulators and other necessary valves shall be provided to interconnect the end labyrinth seals. The piping shall have one common connection to the purchaser's sealing steam supply.

10.6.3.2 The admission and the pressure of the sealing steam shall be automatically controlled. The normal operating sealing steam supply should preferably come from a positive pressure section of the turbine.

10.6.4 Unless otherwise specified, a separate vacuum system shall be furnished to reduce external leakage from the end labyrinth seals and possible contamination of the bearing oil (15.6). Unless otherwise specified, the system shall be supplied loose for mounting and connection by others. Annex F shows a typical labyrinth end seal vacuum system.

10.6.5 All piping and components of the shaft seal and vacuum systems shall be sized for not less than 300 % of the calculated new clearance leakage.

11 Materials

11.1 General

11.1.1 Except as required or not permitted by this standard or by the purchaser, materials of construction shall be selected by the manufacturer for the specified operating and site environmental conditions (11.1.6 and 11.1.7).

11.1.2 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 publicly available standards, including the material grade (see Annex J). 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.

● **11.1.3** The vendor shall specify the optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal.

NOTE The purchaser may specify additional optional tests and inspections, especially for materials used for critical components or in critical services.

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

11.1.5 Minor parts that are not identified (such as nuts, springs, washers, gaskets, and keys) shall have corrosion resistance at least equal to that of parts identified in accordance with 11.1.2 in the same environment.

● **11.1.6** Unless otherwise specified, steam purity limits shall be in accordance with IEC 60045-1 or NEMA SM 24. The purchaser shall specify if there are any corrosive agents in the steam or the environment that exceed the levels specified in IEC 60045-1 or NEMA SM 24 including constituents that can cause stress corrosion cracking.

The vendor should recognize that some steam systems include contaminants such as sodium hydroxide, chlorides, aluminum, phosphates, copper, and lead, and they should consider these when selecting materials.

11.1.7 If austenitic stainless steel parts exposed to conditions that can 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.

11.1.8 Where 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.

11.1.9 In turbines operating on saturated steam, all components in the steam path (e.g. nozzles, blading, diaphragms) shall be made of erosion-resistant material.

11.1.10 Pressure-containing parts shall be steel. In the case of the exhaust casing of noncondensing turbines, this shall be based on the maximum specified exhaust pressure and the maximum no-load exhaust temperature. Alloy steels shall be used for maximum steam temperatures exceeding 410 °C (770 °F).

11.1.11 The material limits for pressure bolting based upon the actual bolting temperature shall be as specified in ISO 15649. Nuts shall conform to ASTM A194, Grade 2H (or ASTM A307, Grade B, case-hardened, where space is limited) or better material.

NOTE For the purpose of this provision, ASME B31.3 is equivalent to ISO 15649.

11.1.12 Material for turbine wheels and shafts shall be forged steel. Unless otherwise approved, 11 % to 13 % chromium steel, titanium, or nickel-copper alloy (similar to ASTM B127) shall be used for nozzles, closing pieces, rotating and stationary blading, shrouding, and steam strainers.

11.1.13 Bearing surfaces (journals and thrust faces) shall be of a material containing less than 2.5 % Cr, to prevent the risk of wire wool type bearing failures.

11.1.14 Low-carbon steels can be notch-sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, steels that are silicon killed, fine grain, and produced with aluminum additions for grain refinement shall be used for pressure-retaining casing fabrication. With purchaser's approval, low-carbon steels using vanadium or columbium (niobium) for grain refinement may be used since these elements can be strong carbide formers as well. Steels made to a coarse grain practice without additions of grain refinement elements (such as ASTM A515) shall not be used.

11.1.15 Structural steel used for structures such as baseplates, supports, exhaust hoods, and lift bar mechanisms shall be selected from the prequalified materials in AWS D1.1. Alternative materials may be used if approved by the purchaser.

11.2 Castings

11.2.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning or any other standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

11.2.2 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.

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

11.2.3.1 Weldable grades of castings shall be repaired by welding, using a qualified welding procedure (including preweld or postweld heat treatment or both, when necessary) as specified in Table 4 (see 11.3). After major weld repairs, and before hydrostatic testing, the complete 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.

11.2.3.2 Cast iron may be repaired by plugging within the limits specified in ASTM A278, ASTM A395, or ASTM A536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

11.2.3.3 All repairs that are not covered by the material specifications shall be subject to the purchaser's approval. All major repairs, as defined by the material specifications, shall be recorded (on a drawing, if appropriate) and reported as part of the vendor's documentation.

NOTE See 7.5.3 for definition of major repair and 7.5.4 for corresponding documentation requirements.

11.2.4 Fully enclosed cored voids, which become fully enclosed by methods such as plugging, welding, or assembly, are prohibited.

11.2.5 Nodular iron castings shall be produced in accordance with an internationally recognized standard such as ASTM A395. The production of the castings shall also conform to the conditions specified in 11.2.5.1 through 11.2.5.6, as follows.

11.2.5.1 The keel or Y block cast at the end of the pour shall have a thickness not less than the thickness of critical sections of the main casting. This test block shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules under microscopic examination shall be in accordance with ASTM A247. Minimum quality levels for critical sections shall be agreed upon between the purchaser and the vendor. Critical sections are typically heavy sections, section changes, and high-stress points. Normally, bosses and similar sections are not considered critical sections of a casting.

11.2.5.2 If critical sections of a casting have different thicknesses, average size keel or Y blocks may be selected in accordance with ASTM A395. Minimum quality levels should be agreed upon between the purchaser and the vendor. Critical sections are typically heavy sections, section changes, and high-stress points. Normally, bosses and similar sections are not considered critical sections of a casting.

11.2.5.3 A minimum of one set (three samples) of Charpy V-notch impact specimens at one-third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y block. These specimens shall have a minimum impact value of 12 Joule (9 ft-lbf), and the mean of the three specimens shall not be less than 14 Joule (10 ft-lbf) at room temperature.

11.2.5.4 Integrally cast test bosses, preferably at least 25 mm (1 in.) in height and diameter, shall be provided at critical areas of the casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, flanges, and other high-stress points as agreed upon by the purchaser and the vendor. Classification of graphite nodules shall be in accordance with ASTM A247.

11.2.5.5 An "as-cast" sample from each ladle shall be chemically analyzed.

11.2.5.6 Brinell hardness tests shall be made on the actual casting at feasible critical sections such as section changes, flanges, and other accessible locations. Sufficient surface material shall be removed before hardness tests are made to eliminate any skin effect. Tests shall also be made at the extremities of the casting at locations that represent the sections poured first and last. These shall be made in addition to Brinell readings on the keel or Y blocks in accordance with 11.2.5.1.

11.3 Welding

11.3.1 Welding and welding repairs shall be performed by welders/operators and in accordance with procedures qualified or prequalified to the requirements in Table 4 or alternate approved standards. Vendor shall define and the purchaser shall approve welding standards to be used. The datasheets in Annex A may be used for this purpose.

Table 4—Welding Requirements

Requirement	Applicable Code or Standard
Welder/operator qualification	ASME *Code*, Section IX or EN 287
Welding procedure qualification	Applicable material specification or, where weld procedures are not covered by the material specification, ASME *Code*, Section IX or ISO 15607
Nonpressure-retaining structural welding such as baseplates or supports	AWS D1.1
Magnetic particle or liquid penetrant examination of the plate edges	ASME *Code*, Section VIII, Division 1, UG-93(d)(3)
Postweld heat treatment	Applicable material specification or ASME *Code*, Section VIII, Division 1, UW 40
Postweld heat treatment of casing fabrication welds	Applicable material specification or ASME *Code*, Section VIII, Division 1

11.3.2 Unless otherwise specified, other welding, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with AWS D1.1 or Section IX of the ASME *Code* or other purchaser approved welding standard.

11.3.3 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. Repair welds shall be nondestructively tested by the same method used to detect the original flaw, consistent with the purchaser's specifications or vendor's quality assurance documents. The minimum level of inspection after the repair shall be by the magnetic particle method for magnetic material and by the liquid penetrant method for nonmagnetic material. If specified, procedures for major repairs shall be subject to review by the purchaser before any repair is made.

11.3.4 Pressure-containing casings made from wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 11.3.4.1 through 11.3.4.5.

11.3.4.1 Before welding, plate edges shall be examined by the magnetic particle method to confirm the absence of laminations.

11.3.4.2 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.

11.3.4.3 The quality control of welds that are inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

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

NOTE Condensing exhaust casings are not considered as pressure-containing. Fabricated low-pressure casings may employ fillet and partial penetration welds.

11.3.4.5 Fabricated casings shall be postweld heat treated, regardless of thickness, in accordance with the requirements in Table 4. Minor appendages may be welded to the casing after postweld heat treatment with qualified weld procedure specifications when welding without postweld heat treatment is permitted by ASME *BPVC*, Section VIII.

11.3.5 Connections welded to pressure casings shall be installed as specified in 11.3.5.1 through 11.3.5.5 up to the first welded or bolted connection. Subsequent piping assemblies using qualified welding process specifications may be welded without postweld heat treatment when permitted by ASME *BPVC*, Section VIII.

● **11.3.5.1** If specified, connection welds shall be 100 % radiography (RT) inspected. Welds that cannot be inspected by RT shall be inspected by ultrasonic (UT) inspection. Magnetic particle inspection or liquid penetrant inspection of welds shall be used where RT or UT is not possible.

● **11.3.5.2** If specified, the proposed connection designs shall be submitted to purchaser for approval before fabrication begins. The drawings shall show weld designs, size, materials, and preweld and postweld heat treatments.

11.3.5.3 All welds shall be heat treated in accordance with internationally recognized standards such as Section VIII, Division 1, Sections UW-10, UW- 40, and UCS-56 of the ASME *Code*.

11.3.5.4 Final heat treatment, when required, shall be carried out after all welding, including piping, has been completed.

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

12 Controls and Instrumentation

12.1 General

The wiring and installation of instrumentation control and electrical systems shall conform to the purchaser's specifications and, unless otherwise specified, shall conform to the requirements of API 614 and API 670.

12.2 Turbine Governing System

12.2.1 The governor system is the primary system necessary to match the turbine output to the application. The governor system includes:

a) speed sensors;

b) governor controller including control logic, input, and output signals;

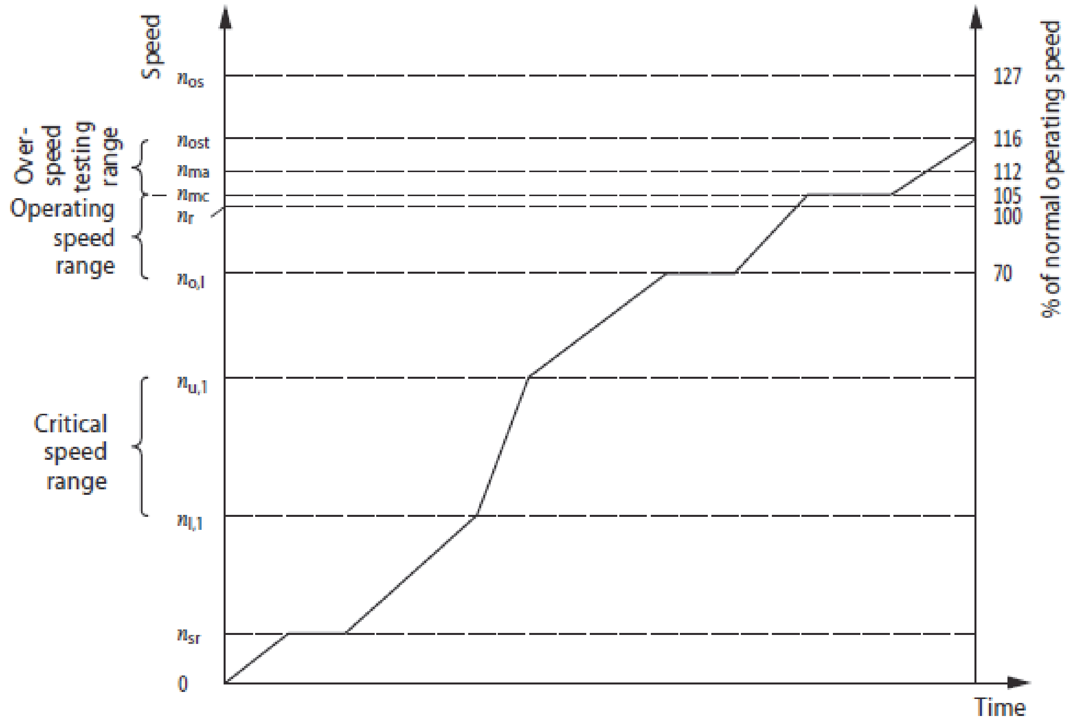
c) actuator(s);

d) position feedback transducers;

e) governor-controlled valve(s).

If the vendor provides the governor system with the turbine, the vendor shall have unit responsibility for the entire governor system. For all components (i.e. governor control function, logic processor, etc.) of the governor system provided by the purchaser, the turbine vendor shall review and comment on the governor system design and its suitability for providing accurate and reliable speed control and other specified control functions. The turbine vendor and purchaser shall mutually agree on the governor system to be used.

NOTE The relationship between the various turbine speeds is illustrated in Figure 7.



Key

n_{sr}	slow roll speed	n_{mc}	maximum continuous speed
$n_{l,1}$	minimum critical speed	n_{ma}	maximum allowable speed rise
$n_{u,1}$	maximum critical speed	n_{ost}	overspeed trip speed = 116 % n_r
$n_{o,l}$	minimum operating speed	n_{os}	maximum temporary overshoot speed = 127 % n_r
n_r	rated operating speed		

Figure 7—Mechanical Drive Turbine Ramp Speeds

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

NOTE Speed control may not be required when the turbine is to be used in tandem with a main driver and the main driver controls the speed of the complete train.

12.2.3 The speed of the turbine shall be controlled by a dedicated governor control function. The dedicated governor function shall only control a single turbine. Multiple governor functions can reside in the same control system.

12.2.4 The governor control function shall be performed in an electronic microprocessor-based system. The governor system shall operate to the performance levels as stated in 12.2.6. Additional control functions not related to the governor system shall not degrade the performance. The governor system shall be protected from inadvertent changes that affect performance or safe operation. In addition, the unit shall be powered by a purchaser supplied uninterruptible electrical power source.

12.2.5 The governor minimum and maximum speeds shall consider the minimum and maximum speeds of the driven equipment and the turbine. The highest minimum and lowest maximum speed shall be selected.

12.2.6 Unless otherwise specified, the governing system shall comply with the requirements of Items a) to c), as follows.

a) The speed regulation at rated speed and rated steam inlet and exhaust conditions shall not exceed 0.5 %. Speed regulation is defined as:

$$\frac{n_{\mathrm{P0}} - n_{\mathrm{PR}}}{n_{\mathrm{PR}}} \times 100\ \% \tag{16}$$

where

n_{P0} is the speed at zero power;

n_{PR} is the speed at rated power.

b) The steady state speed variation at constant load, rated speed, rated power, and rated steam inlet and exhaust conditions shall not exceed 0.25 %. Speed variation is defined as:

$$\frac{n_{\mathrm{i,max}} - n_{\mathrm{i,min}}}{2 \times n_{\mathrm{r}}} \times 100\ \% \tag{17}$$

where

$n_{\mathrm{i,max}}$ is the maximum instantaneous speed;

$n_{\mathrm{i,min}}$ is the minimum instantaneous speed;

n_{r} is the rated speed;

c) The maximum speed rise shall not exceed 7 % of the maximum continuous speed. The maximum speed rise is the maximum momentary increase in speed when the turbine is developing rated power at maximum continuous speed and rated steam inlet and exhaust conditions, and the load is suddenly and completely reduced to zero.

NOTE This section does not apply to generator drives in droop mode.

12.2.7 A multi-toothed speed sensing surface shall be provided in accordance with 8.4 and API 670.

12.2.8 The speed governor system shall include at least two speed sensors dedicated for speed control. The speed sensors are not to be shared with the overspeed shutdown system. The speed governor control function shall select the higher of the two signals from the speed-sensing elements for control. If three probes are installed, the governor shall select the middle of the three signals for control. The failure of any speed-sensing element shall initiate an alarm only. The failure of all elements shall initiate a shutdown.

12.2.9 The design of the speed governor shall include but not be limited to the following:

a) an assignable speed range corresponding to the normal range of operation (typically, 70 % to 105 % of rated operating speed);

b) speed set point adjustment;

c) remote or process controlled speed set point adjustment;

d) digital speed indication;

e) individual outputs to each control mechanism actuator;

f) adjustable speed ramp rate;

g) slow roll control;

h) critical speed band avoidance;

i) high speed shutdown [set at maximum allowable speed rise (n_{ma})];

j) manually activated override with controlled access for testing the overspeed shutdown system;

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

12.2.10 For mechanical drive, the speed of the turbine shall vary linearly with the set point signal. An increase in set point signal shall increase turbine speed. The control signal shall act to adjust the set point of the governor system. The speed of the machine shall vary linearly and directly with the control signal. Unless otherwise specified, the control range shall be from the maximum continuous speed to 95 % of the minimum speed required for any specified operating condition or 70 % of the maximum continuous speed, whichever is lower.

12.2.11 Automatic or manual adjustment of the control signal or failure of the control signal shall not prevent the governor from limiting the speed to the maximum allowable speed.

12.2.12 The governing system shall be design to control the turbine speed at slow roll speed (typically, 400 rpm to 500 rpm) coupled and uncoupled to the driven equipment. The governing system shall be designed to accelerate the turbine coupled to the driven equipment to slow roll speed from zero speed.

NOTE This assumes the trip valve is open and governor valves are closed when the start signal is given.

● **12.2.13** If specified, a combination of control modes, such as single controlled extraction/induction, shall be provided.

12.2.14 The turbine supplier shall specify any control mode limits required to prevent operating the turbine beyond its mechanical limits.

12.2.15 The level of redundancy and fault tolerance shall be as required to meet the uninterrupted service expectation. Unless otherwise specified, the governor electronic components (speed sensors, circuit boards, coils, position transducers, power supplies, etc.) shall be redundant with adequate diagnostics and fault tolerance to allow continuous operation on a single component failure. Facilities shall be provided to allow replacement of a failed governor circuit board or power supply without affecting the continuous operation of the governor.

12.3 Turbine Shutdown System

12.3.1 General

12.3.1.1 A shutdown system capable of shutting down the turbine shall be provided. The turbine shutdown system shall include, but not be limited to, the following:

a) input sensors;

b) logic solver devices (one or more including overspeed trip function);

c) electro-hydraulic solenoid valves;

d) emergency trip valve(s)/combined trip and throttle valve(s).

The shutdown system shall not be prohibited in any way from executing a trip of the turbine by any other system. Detailed shutdown system requirements are described in API 670.

12.3.1.2 If the turbine vendor provides the shutdown system with the turbine, the turbine vendor shall have unit responsibility for the entire shutdown system. If the trip system is not supplied by the turbine vendor, the supplier has to supply the response time of the trip systems components and the turbine vendor shall review and comment on the proposed system. The unit shall be powered by a purchaser-supplied uninterruptible electrical power source.

12.3.1.3 The turbine shutdown system shall include diagnostics, testing, and online repair features. If online modifications or repairs are made, the functionality of the repaired component shall be verified.

● **12.3.1.4** If specified, the design of the turbine shutdown system shall conform to IEC 61508/IEC 61511.

12.3.1.5 Governor controlled valve(s) shall be equipped with a closed position feedback sensor(s). Prior to resetting the system, the governor controlled valve(s) shall be confirmed closed by the system as a permissive to start.

NOTE If the turbine has a trip and throttle valve, the governor valves may be opened prior to starting the turbine.

12.3.1.6 Activation of any shutdown device shall cause the governor-controlled valve(s) and the trip valve(s)/combined trip and throttle valve(s) to close, and activate nonreturn valve actuator(s), if supplied. The governor controlled valves shall be designed to fail close on loss of actuator power or control signal (hydraulic, pneumatic, or electrical).

12.3.1.7 The overspeed shutdown function shall be part of the turbine shutdown system. The overspeed function may be included in the shutdown system logic solver or in a dedicated overspeed logic solver. Detailed overspeed detection requirements are described in API 670.

The system shall prevent the turbine rotor speed from exceeding the limits defined in 8.1.1 on an instantaneous, complete loss of coupled inertia and load while operating at the rated conditions. In the event of loss of load without coupling failure, and unless otherwise specified by the driven equipment vendor, the system shall prevent the speed from exceeding 120 % of rated speed.

NOTE The recommended overspeed trip set point (n_{ost}) is 116 % of the turbine rated speed or driven equipment rated speed, whichever is less.

● **12.3.1.8** If specified, a turbine with an exhaust pressure less than atmospheric pressure shall be provided with an exhaust vacuum breaker actuated by the shutdown system. Details of such a system shall be agreed by the purchaser and the turbine vendor.

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

12.3.1.9 On controlled extraction turbines, the vendor shall supply a nonreturn valve, equipped with a fail-closed actuator to assist in closing the valve, on each extraction line. The actuator on these valves shall be actuated by the turbine shutdown system. The manufacturer, model, quantity, and location of the device(s) shall be agreed by the purchaser and the turbine vendor.

Nonreturn valve(s) should not be installed in a vertical line with downward flow.

NOTE 1 Nonreturn valves are normally mounted directly to steam turbine extraction connections or as close as possible to the turbine to avoid trapping large volumes of steam, which can keep the turbine operating when extraction valves do not fully close.

NOTE 2 Location of nonreturn valves in piping below the turbine requires that low-point drain provisions be furnished to eliminate water from the extraction line before start-up and to eliminate the accumulation of water during operation with no extraction flow.

NOTE 3 Location of hydraulically actuated nonreturn valves in piping below oil console level can result in drainage problems. Alternative actuation methods may be required.

12.3.1.10 On turbines with uncontrolled extractions, two nonreturn valves in series shall be provided on each extraction complete with features defined in 12.3.1.9.

12.3.2 Electronic Overspeed Detection System

12.3.2.1 An overspeed detection system based on three independent measuring circuits and two-out-of-three voting logic in accordance with API 670 shall be supplied.

12.3.2.2 A multi-toothed speed sensing surface shall be provided in accordance with 8.4 and API 670. This surface may be shared by the speed governor, overspeed shutdown system, and tachometer.

12.3.3 Electro-hydraulic Solenoid Valves

12.3.3.1 The turbine shall be provided with a minimum of two separate electro-hydraulic solenoid-operated valves located in the shutdown system.

12.3.3.2 Solenoid valves shall be continuously rated with Class H insulation, in accordance with IEC 60072.

12.3.3.3 Solenoid valves shall be de-energized to shutdown. The solenoid valves shall be in parallel, be close to the trip valve(s) or trip and throttle valve(s), and have no other device between them and the trip valve(s) or trip and throttle valve(s) except test isolation valves. See Figure 8.

NOTE Energized to trip systems will not fail in the safe direction. They can fail due to power failures, loose wires, blown fuses, and open coils preventing the actuation of the final trip element. These failures are often covert (unrevealed) failures and may exist for long periods of time without being detected leaving the equipment unprotected.

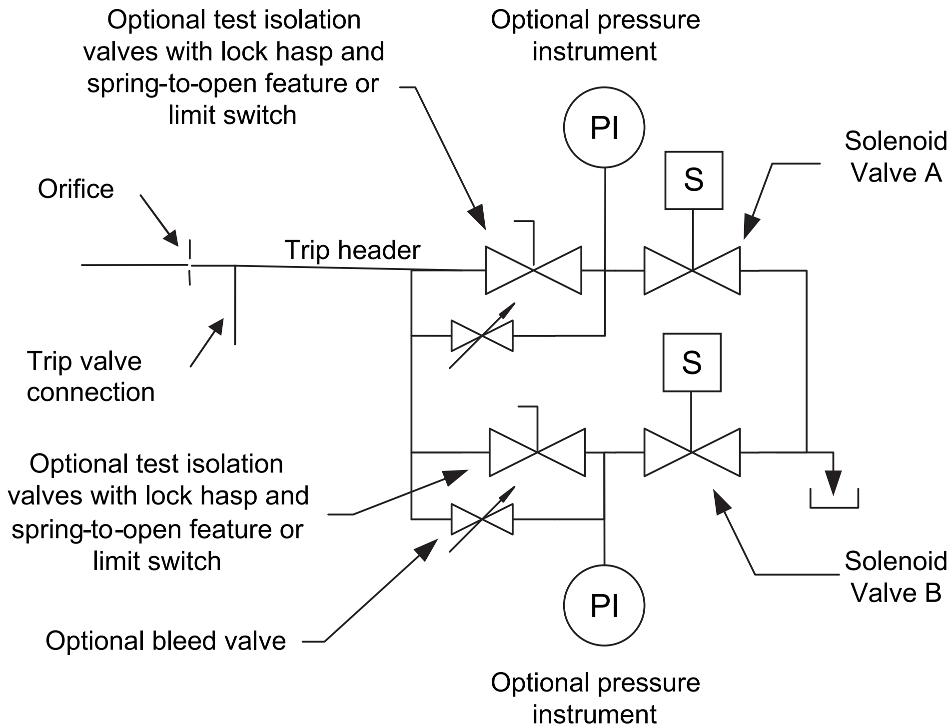
● **12.3.3.4** If specified, a fault tolerant design voting scheme that allows continued operation upon failure of a single solenoid without defeating the trip function shall be provided. Fault tolerant schemes to include two out of three or two out of four voted solenoid valve configurations.

NOTE Nuisance trips can occur with solenoid failure on systems with only a single solenoid. This may not be acceptable for applications requiring extended periods of continuous operation.

12.3.3.5 The trip solenoids valves shall be provided with facilities to allow testing of the solenoid valve function while the turbine is in operation. An example can be seen in Figure 8. Facilities or procedures shall be implemented to ensure any manual block valves used during the test are not left in the wrong position after the test thus defeating the function of the trip system.

NOTE The most common cause of failure for an electro-hydraulic valve is silting of the spool or poppet, preventing timely opening of the valve on demand. This is a common problem for valves that remain closed for long periods of time. Periodic testing is required to verify that the valves will perform on demand and to exercise the spool or poppet.

12.3.3.6 Operation of solenoid valves shall be initiated by the turbine shutdown system.



The optional bleed valves shall be sized so that in their fully open position the flow rate will be too low to cause a trip. The bleed valve and pressure instrument shall allow verification of proper operation of the solenoid valve in both the open and closed positions. Alternatively, an orifice and block valve may be used in place of the bleed valve.

Figure 8—Trip Solenoid Valves—1-out-of-2 Configuration (1oo2)

12.3.4 Trip Valves/Combined Trip and Throttle Valves

● **12.3.4.1** A separate independent trip valve(s) or combined trip and throttle valve(s), as specified, shall be provided for each steam inlet including admission inlets. In the remainder of this section, the term trip valve refers to both separate trip valves and combined trip and throttle valves.

NOTE Trip valve(s) operate in the shut (tripped) or fully open positions only. In addition to the functions provided by trip valve(s), combined trip and throttle valve(s) provide intermediate valve positioning for use during start-up or during abnormal conditions.

● **12.3.4.2** If specified, duplicate trip valves shall be provided, arranged in parallel. Each trip valve shall be sized to pass the full steam flow.

In normal operation, one valve shall be closed. The purpose of the second valve is to enable the normally open valve to be completely tested with the turbine on line.

Failure of trip valves to close when required is a common cause of turbine failure. It is recommended that trip valves should be fully tested at regular intervals. Where the turbine cannot be conveniently taken out of service for this purpose consideration should be given to installing two trip valves.

Where duplicate trip valves are provided, the steam piping shall be designed to allow for the thermal expansion and entrapped energy effects resulting from steam flow through either or both valves.

12.3.4.3 The trip valve(s) shall be designed to be closed by the action of a spring. Unless otherwise specified, the valve(s) shall be held open by direct hydraulic means. Any shutdown signal shall cause the valve(s) to close.

NOTE The use of fully hydraulic operated trip valves allows higher spring closing forces and avoids friction associated with mechanical latches.

12.3.4.4 The design of trip valve(s) shall include, but not be limited to, the following features:

a) erosion- and corrosion-resistant material on the stem and seating surfaces;

b) prevention of steam contaminate deposits on the valve stem that inhibit closure;

c) spring loading and steam flow and pressure to assist closure;

d) above and below seat drain connections, as required by the body style and mounting position, and valve stem leak-off connections;

e) reset and start-up capability with maximum differential pressure across the valve;

f) partial stroking capability that does not interrupt operation of the turbine when redundant valves are not specified; the arrangement shall prevent full closure during an exercise test but shall permit the valve to fully close if a shutdown condition occurs;

g) replacement of wearing parts with the valve in place;

h) corrosion-resistant steam strainer;

i) valve disk designed to prevent the rotation of the valve disk on seat;

j) valve stem, stem bushing, main valve disk, and all sliding surfaces shall have hardened contact surfaces.

NOTE Consideration should be given to the use of a back-seated valve stem to minimize leakage and fouling.

12.3.4.5 The trip valve steam strainer shall be designed to prevent in-service failure. The strainer shall be removable without dismantling any of the inlet steam piping. The effective free area of the strainer shall be at least twice the cross-sectional area of the valve inlet connection. The steam strainer shall be capable of withstanding a pressure differential at least equal to 25 % of the inlet pressure.

12.3.4.6 The trip valve shall not depend on steam flow assistance to meet the required closure time. The closure time of the valve shall be verified during the mechanical running test.

12.3.4.7 The time from the overspeed condition to full closure of the trip valve shall not exceed the time calculated by the turbine vendor to meet the requirements of 12.3.1.1. The calculation methodology shall be in accordance with Annex D.

If the logic solver is provided by the purchaser, the response time of the logic solver shall be no more than defined in API 670.

12.4 Other Alarms and Shutdowns

12.4.1 An alarm/shutdown system shall be provided in accordance with API 614.

12.4.2 The turbine vendor shall advise the purchaser of any alarms and/or shutdowns considered essential to safeguard the turbine.

● **12.4.3** The purchaser shall specify the alarms and shutdowns required. As a minimum, to safeguard the turbine, these should include the following.

a) Alarms:

— overspeed shutdown system fault,

— failure of any one governor speed sensor,

— low lube oil pressure,

— high exhaust pressure,

— high radial vibration,

— high axial displacement,

— high bearing temperature,

— low control oil pressure,

— low/high extraction pressure,

— low steam inlet temperature,

— high exhaust temperature (condensing turbines),

— governor fault,

— turning gear fail to engage when shutdown (if applicable).

b) Shutdowns:

— overspeed detected by turbine shutdown system (see 12.3),

— overspeed detected by governor,

— failure of all governor speed sensors,

— low-low lube oil pressure,

— high-high radial vibration (if specified),

— high-high axial displacement,

— high-high bearing temperature (if specified).

12.4.4 Any failures of the governing system that would result in unstable speed control or unsafe operation shall initiate a turbine shutdown.

12.4.5 In addition to the shutdowns listed above, a manual trip shall be provided local to the turbine to allow an operator to trip the unit.

12.4.6 Any mechanical/hydraulic condition resulting in a loss of governor oil pressure that activates the trip valve(s) shall also trip the turbine shutdown system.

NOTE The interlock is necessary to activate the turbine and process shutdown systems if the turbine is manually tripped or if a component failure occurs.

● **12.4.7** The purchaser shall specify the extent to which the alarm/shutdown system is to be supplied by the turbine vendor.

NOTE This can conveniently be achieved by the use of a responsibility matrix.

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

12.4.9 Unless otherwise specified, the alarm/shutdown system shall comply with the requirements of API 614, API 670, and the following.

a) When any alarm/shutdown system component malfunctions, a distinguishable alarm shall be initiated.

b) When a shutdown system component malfunction results in the system being unable to recognize a shutdown condition, the turbine shall be shutdown.

c) Following an alarm/shutdown system malfunction that results in the system being unable to recognize an alarm condition, all other alarms and all shutdowns shall remain functional.

NOTE It is accepted that with some systems, particularly those based on conventional direct-acting instruments, complete compliance with the requirements of Items a) to c) may not be possible.

● **12.4.10** If specified, the alarm/shutdown system shall incorporate an event recorder to record the order of occurrence of alarms and shutdowns.

NOTE The special-event recorder normally associated with a DCS may not have a sufficiently fast scanning rate.

12.4.11 With the exception of the steam trip and throttle valve, it shall be possible to test every component of every shutdown function while the equipment is in operation. The testing of components associated with a shutdown function shall not require disarming of any other shutdown function nor any alarm function. Trip valves that cannot be fully functionally tested may be tested partially, e.g. by partial stroke test.

12.4.12 If bypasses are used on trip circuits, they shall have means to prevent inadvertent defeating of the shutdown system.

12.4.13 Unless otherwise specified, the shutdown system shall incorporate a first-out indication to display which parameter first reached the trip level, in the event that multiple shutdowns result from a single initial event.

12.5 Instrument and Control Panels

12.5.1 Unless otherwise specified, instrument and control panels shall conform to API 614.

● **12.5.2** Unless otherwise specified, panels shall be made of steel plate at least 3 mm thick, reinforced, self-supporting, and closed on the top and sides. If specified, the backs of panels shall be closed to minimize electrical hazards, to prevent tampering or to allow purging for safety or corrosion prevention. All instruments shall be flush-mounted on the front of the panel and all fasteners shall be of corrosion-resisting materials.

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

12.6 Local Instrumentation

12.6.1 General

The local instrumentation shall conform to purchaser's specification and, unless otherwise specified, shall conform to the requirements of API 614 and API 670.

12.6.1 Tachometers

12.6.1.1 Unless otherwise specified, two electronic digital-speed indicators shall be furnished. The minimum tachometer range shall be from 0 % to 125 % of the maximum continuous speed. One indicator shall be locally mounted and the other shall be supplied to the purchaser for remote mounting.

12.6.1.2 The speed signals may be obtained from the speed sensors provided for turbine governing or from independent sensors (see 12.2.7 and 12.2.8).

12.6.2 Temperature Gauges

12.6.2.1 Dial temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 100 mm (4 in.) in diameter and bimetallic or gas-filled and, unless otherwise agreed, shall have black printing on a white background.

12.6.2.2 Liquid-filled temperature gauges shall not be used.

12.6.3 Thermowells

Thermowells shall be in accordance with API 614.

12.6.4 Thermocouples and Resistance Temperature Detectors

Thermocouples and resistance temperature detectors shall be in accordance with API 614.

12.6.5 Pressure Gauges

Pressure gauges shall be in accordance with API 614.

13 Electrical Systems

Electrical systems shall conform to the purchaser's specifications and, unless otherwise specified, shall conform to the requirements of API 614 and API 670.

14 Piping and Appurtenances

14.1 General

14.1.1 Piping design, fabrication, examination, and inspection shall be in accordance with the codes and standards specified and shall conform to the requirements of API 614.

14.1.2 Threaded connections shall not be seal-welded. If welding in a particular location is acceptable, the connection shall be welded and not threaded.

14.1.3 Auxiliary systems are defined as 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;

f) drains and vents.

Auxiliary systems shall comply with the requirements of Table 5.

14.1.4 Unless otherwise specified, pipe-flange gaskets shall be spiral-wound metal or metal-jacketed for steam temperatures above 260 °C (500 °F) or steam gauge pressures above 2800 kPa (400 psi). The manufacturer's standard gasket may be used below these limits. For all steam piping, spiral-wound metal gaskets shall have inner and outer rings.

14.1.5 Auxiliary piping to the turbine shall have breakout spools or other flange connections to allow for maintenance and for removal of the entire turbine. Provision for bypassing the bearings (and seals if applicable) of machines and drivers during oil system flushing operations shall be provided. Unless otherwise specified, these spools shall be furnished by the equipment vendor.

NOTE Generally this is accomplished by short spool pieces at the equipment.

14.2 Oil Piping

Oil piping design, fabrication, examination, and inspection shall be in accordance with API 614.

14.3 Instrument Piping

Instrument piping design, fabrication, examination and inspection shall be in accordance with API 614.

14.4 Steam Piping

14.4.1 Steam piping design, fabrication, examination, and inspection shall be in accordance with ASME B31.3.

- **14.4.2** The extent of and requirements for steam piping to be supplied by the vendor will shall be specified by the purchaser.

- **14.4.3** If specified, the vendor shall review the design of all piping, appurtenances and supports immediately upstream and downstream of the equipment. The purchaser and the vendor shall agree on the scope of this review.

15 Accessories

15.1 Couplings and Guards

15.1.1 Unless otherwise specified, all couplings and guards between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment.

- **15.1.2** Unless otherwise specified, couplings between the driver and driven equipment shall conform to API 671 and shall be nonlubricated. The make, type, and mounting arrangement of the couplings shall be as specified by the purchaser and agreed by the vendors of the driver and driven equipment.

15.1.3 The coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting torque at least equal to the coupling continuously rated torque.

Unless otherwise specified, integral flanged coupling hub shall be provided. If an integral flange cannot be supplied, a keyless hydraulically fitted coupling shall be provided. Keyed coupling require purchaser approval.

- **15.1.4** If specified, the machine vendor shall provide plug and ring gauges in accordance with API 671, Fourth Edition, Sections 11.5 and 11.6.

15.1.5 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.

15.1.6 Coupling mass simulator(s) (or by agreement, moment simulators), in accordance with API 671, shall be provided to enable the turbine to be properly tested before shipment.

Table 5—Minimum Requirements for Piping Materials

System	Steam		Cooling Water		Lube Oil	
	≤500 kPa (75 psig)	≥500 kPa (75 psig)	Standard (≤NPS 1)	Optional	≤NPS 1	≥NPS 1 1/2
Pipe	Seamless [a]	Seamless [a]		ASTM A53 Type F Schedule 40, galvanized to ASTM A153		ASTM A312, Type 304 or 316 stainless steel [b]
All valves	Carbon steel, Class 800	Carbon steel, Class 800	Bronze, Class 200	Bronze, Class 200	Caron steel, Class 800	Carbon steel, Class 800
Gate and globe valves	Bolted bonnet and gland	Bolted bonnet and gland			Bolted bonnet and gland	Bolted bonnet and gland
Pipe fitting and unions	Forged Class 3000	Forged Class 3000	ASTM A338 and A197, Class 150 malleable iron, galvanized to ASTM A153	ASTM A338 and A197, Class 150 malleable iron, galvanized to ASTM A153	Stainless steel	Stainless steel
Tube Fittings	Carbon steel, compression, manufacturer's standard		Manufacturer's standard		Carbon steel, compression, manufacturer's standard	
Fabricated joints ≤1 1/2 in.	Threaded	Socket welded	Threaded	Threaded		Carbon steel
Fabricated joints >2 in.	Slip-on flanges	Socket-weld or weld-neck flange	Purchaser to specify	Purchaser to specify		Carbon steel slip-on flange
Gaskets	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel. Inner and outer rings.	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel. Inner and outer rings.				Type 304 or 316 stainless steel, spiral wound
Flange bolting	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H				

Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A524; or API 5L, Grade A or Grade B.

Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and ASTM A181.

Stainless steel piping shall conform to ASTM A312.

NOTE This table does not take into consideration high-temperature pipe and bolting materials required for steam piping, see ASME B31.3.

[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.

15.1.7 Idling adapter(s) (solo plates), and bolting in accordance with API 671, shall be furnished, if required, to enable the turbine to be run uncoupled from the driven equipment without requiring removal of the half coupling. The idling adapter(s) shall be supplied to the purchaser as part of the special tools.

15.1.8 Unless otherwise specified, the turbine coupling hub(s) shall be mounted by the turbine manufacturer.

15.1.9 The coupling guard shall comply with API 671, Fourth Edition, Annex H entitled “Coupling Guards.”

15.2 Mounting Plates

15.2.1 General

● **15.2.1.1** The equipment shall be furnished with soleplates or a baseplate, as specified. Mounting plate refers to both baseplates and soleplates.

NOTE Typical mounting plate arrangements are shown in Annex E.

15.2.1.2 Direct attachment of equipment feet to the foundation using the anchor bolts shall not be permitted. Mounting plates shall be of sufficient strength and rigidity to transfer the applied forces to the foundation. Mounting plates (baseplates and soleplates) shall comply with the requirements of 15.2.1.2.1 through 15.2.1.2.23.

15.2.1.2.1 Mounting plates shall be furnished with horizontal (axial and lateral) jackscrews. These jackscrews shall meet the following requirements.

a) The lugs holding these jackscrews shall be attached to the mounting plates in such a manner that they do not interfere with the installation of the equipment, jackscrews, or shims.

b) Means for moving the equipment vertically for removal or insertion of shims shall be provided.

c) Precautions shall be taken to prevent vertical jackscrews (if provided) in the equipment feet from marring the shimming surfaces.

d) Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of lateral and axial jackscrews provided on the mounting plate. Alternative methods of lifting the equipment for the removal or insertion of shims or for moving the equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed. Such arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews.

e) Alignment jackscrews shall be plated for rust resistance.

15.2.1.2.2 The alignment shims shall be provided by the vendor in accordance with API 686, Second Edition, 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.

15.2.1.2.3 All machinery mounting surfaces on the mounting plate shall be machined flat and parallel to the axial plane(s) of the machinery mounting feet after fabrication and shall extend at least 25 mm (1 in.) beyond the outer three sides of the equipment feet. These mounting surfaces shall meet the following requirements:

a) each mounting surface shall be machined to a finish of 6.3 μm (250 μin.) arithmetic average roughness (Ra) or smoother;

b) to prevent a soft foot, when the machine is installed on the mounting plate, all mounting surfaces in the same horizontal plane shall be within 25 μm (0.001 in.);

c) each mounting surface shall be machined within a flatness of 40 μm/m (0.0005 in./ft) of mounting surface;

d) different mounting planes shall be parallel to each other within 50 μm (0.002 in.);

e) hold-down bolt holes shall be drilled perpendicular to the mounting surfaces, machined or spot faced to a diameter suitable for a fully eccentric washer next to the hole to allow for equipment alignment. The hole shall be at least 12 mm (0.5 in.) larger in diameter than the hold-down bolt. Holes shall not be slotted.

15.2.1.2.4 Mounting plates and 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.).

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

15.2.1.2.6 The upper and lower surfaces of mounting plates and any separate pedestals mounted thereon shall be machined parallel.

15.2.1.2.7 Unless otherwise specified, anchor bolts shall be furnished by the purchaser.

15.2.1.2.8 Anchor bolts shall not be used to fasten machinery to the mounting plates.

15.2.1.2.9 Grouted mounting plates shall be adequately sized to limit the static loading to 0.7 N/mm^2 (102 psi) on the grout.

15.2.1.2.10 The diametrical clearance between anchor bolts and the anchor bolt holes in the mounting plates shall be at least 6 mm (0.24 in.).

NOTE This is required to assist in aligning and setting the baseplate or soleplates over the foundation anchor bolts.

15.2.1.2.11 Unless otherwise specified, mounting plates shall be supplied with vertical levelling screws for field levelling. A levelling screw shall be provided near each anchor bolt. If the equipment and mounting plates are too heavy to be lifted using levelling screws, the equipment vendor shall provide alternate method. The design of the alternative method shall be included in the proposal. Shims or wedges shall not be used.

NOTE Shims and wedges, if left in place after grouting, may cause “hard” spots that interfere with the grout’s ability to provide uniform base support. They may also allow moisture penetration and the resultant corrosion and grout spalling.

15.2.1.2.12 Mounting plate surfaces that are embedded in grout shall have 50 mm (2 in.) radiused minimum outside corners (in the plan view). The embedded edges shall be chamfered or rounded. See Figure E.1, Figure E.2, Figure E.3, and Figure E.4. All baseplates shall have radiused corners appropriate to the baseplate design.

15.2.1.2.13 Hold-down bolts used to attach the equipment to the mounting plates and all jackscrews shall be supplied by the vendor.

15.2.1.2.14 When the machine is properly aligned on the mounting plate in the shop, each hold-down bolt shall have a minimum clearance of 1.5 mm (0.06 in.) between the bolt and the bolt hole.

NOTE Hold-down bolts need adequate clearance within the bolt holes so the machinery can be moved laterally during final field alignment without becoming bolt bound.

15.2.1.2.15 If leveling plates are specified, they shall be steel plates at least 19 mm ($^3/_4$ in.) thick. They shall be circular in shape in the plan view.

15.2.1.2.16 Adequate working clearance shall be provided at the hold-down and jack bolt locations to allow the use of standard socket or box wrenches and to allow the equipment to be moved using the horizontal and vertical jackscrews.

● **15.2.1.2.17** Unless otherwise specified, epoxy grout shall be used for machines mounted on concrete foundations. The purchaser shall specify the manufacturer of the epoxy grout to be used for field installation.

15.2.1.2.18 The vendor shall blast-clean in accordance with ISO 8501 Grade Sa2 or SSPC SP6, all grout contact surfaces of the mounting plates and coat those surfaces with a primer compatible with epoxy grout.

NOTE Epoxy primers have a limited life after application.

15.2.1.2.19 The equipment vendor shall provide details of the actual epoxy primer used.

15.2.1.2.20 All mounting surfaces that are not to be grouted shall be coated with a rust preventive immediately after machining.

15.2.1.2.21 Unless otherwise specified, mounting plates shall not be drilled for components to be mounted by others.

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

15.2.2 Baseplates

● **15.2.2.1** If a baseplate is specified, the purchaser will 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. Unless otherwise specified, multi-section baseplates shall have machined and doweled mating surfaces that shall be bolted together to ensure accurate field reassembly.

NOTE A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) can require fabrication in multiple sections because of shipping restrictions.

15.2.2.1.1 Leakage from baseplate mounted components shall be contained within the baseplate. Drain connections shall be provided at containment low points to permit removal of liquid accumulations.

15.2.2.2 Unless otherwise specified, 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.

15.2.2.3 The baseplate shall be constructed with longitudinal steel beams and full support cross members. Cross members shall be located underneath the support plane of the turbine and all turbine-driven equipment. All baseplate structural welds shall be continuous (i.e. not intermittent stitch welding).

● **15.2.2.4** If specified, nonskid decking or grating covering all walking and working areas shall be provided on the top of the baseplate. If, after grouting, the purchaser plans to completely fill the baseplate with cement as a finished surface, decking or grating is not required.

15.2.2.5 If horizontal solid-decked surfaces are provided, they shall be sloped to avoid collection of liquid.

● **15.2.2.6** If specified, the baseplate shall be designed for column mounting and shall be sufficient rigidity to be supported at specified points without continuous grouting under structural members. The purchaser and the vendor shall agree upon the baseplate design.

● **15.2.2.7** 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 purchaser and the vendor shall agree upon the details of such features. Where leveling pads or targets or both these are supplied, they shall be accessible with the baseplate on the foundation and the equipment mounted.

15.2.2.8 When leveling pads or targets are provided, the pads or targets shall located close to the machinery support points and be accessible for field leveling with the equipment mounted and the baseplate on the foundation. The leveling pads and targets shall have protective removable covers.

15.2.2.9 For baseplates longer than 6 m (20 ft), additional pads and targets shall be provided at intermediate points.

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

CAUTION—For safety reasons, special care and attention can be given to the stability of the lifting system to prevent overturning of the equipment.

Lifting lugs attached to the baseplate shall be designed using a maximum allowable stress of one-third of the specified minimum yield strength of the material. Welding applied to lifting lugs shall be full penetration continuous welds and be in accordance with AWS D1.1 or other agreed upon structural code. The welds shall be 100 % NDE tested in accordance with the applicable code. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the equipment mounted on it.

15.2.2.11 If the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 0.01 m^2 (20 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members and are to be placed in areas that will minimize potential for creating personnel tripping hazards. Where practical, the holes shall be accessible for grouting with the equipment installed. 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, metallic covers with a minimum thickness of 1 mm (16 gauge) shall be provided. Vent holes at least 13 mm ($^1/_2$ in.) in size shall be provided at the highest point in each bulkhead section of the baseplate.

15.2.2.12 Baseplate supports for the equipment shall be located directly beneath the equipment feet and shall extend in line vertically to the bottom of the baseplate.

● **15.2.2.13** 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 sub-soleplates or structural steel members to facilitate field leveling.

15.2.2.14 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 surfaces shall be in one plane after the baseplate sections are doweled and bolted together.

● **15.2.2.15** If specified, sub-soleplates shall be provided by the vendor.

15.2.2.16 Unless otherwise specified, oil reservoirs shall be separate from the baseplate.

15.2.2.17 For open baseplate compartments that are not filled with grout, decking or grating over the compartment shall be removable for access to internal structural members or other components. Provision shall be made to allow draining of the spaces between structural members.

15.2.3 Soleplates and Sub-soleplates

15.2.3.1 Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall the plates be less than 40 mm (1 $^1/_2$ in.) thick.

● **15.2.3.2** Soleplates shall be large enough to extend beyond the feet of the equipment in all directions and shall be designed such that machine feet do not cover the anchor bolts. If specified, anchor bolt holes shall be counter bored so that the hold-down nuts do not extend beyond the upper surface of the soleplate.

15.2.3.3 If sub-soleplates are used, soleplates shall be fully machined top and bottom.

● **15.2.3.4** If sub-soleplates are specified, they shall be steel plates at least 25 mm (1 in.) thick. The finish of the sub-sole plates' mating surfaces shall match that of the soleplates.

15.3 Relief Valves

15.3.1 The vendor shall furnish the relief valves that are to be installed on equipment or on vendor supplied piping. The purchaser shall furnish other relief valves. The vendor shall advise the purchaser of the flow rate, set pressure, and temperature for purchaser's use in relief valve sizing and selection. The vendor's quotation shall list all relief valves and shall clearly indicate those to be furnished by the vendor. Sentinel valves shall not be used.

15.3.2 The sizing, selection, and installation of relief valves shall meet the requirements of API 520, Eighth Edition, Parts I and 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 size and setting of relief valves supplied by others required to protect the equipment. Relief valve sizes and set pressures shall take account of all possible modes of equipment failure.

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

15.4 Lubrication and Control-oil System

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

● **15.4.2** If specified, the turbine vendor shall furnish a pressurized oil system that conforms to API 614. The oil system shall supply oil at a suitable pressure or pressures, as applicable, to the following:

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

b) any continuously lubricated couplings;

c) the control-oil system;

d) the shutdown system.

15.4.3 If the pressurized oil system is furnished by others, the turbine vendor shall:

a) define the steady and transient oil-flow and pressure requirements, the degree of filtration required, and the maximum heat load imposed;

b) furnish piping to a single feed connection for each pressure level. One drain connection shall be provided for all oil to be returned to the reservoir;

c) define the rundown and cooldown time for rotor protection;

d) define the emergency power requirements for turning gear.

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

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

15.4.5 Any points that require grease lubrication during operation and that cannot be easily and safely accessed during operation shall be provided with austenitic stainless steel extension lines shielded from heat as necessary.

15.5 Gland Vacuum Systems

15.5.1 Unless otherwise specified, a gland vacuum system shall be furnished by the vendor (see typical system in Annex F). It shall include a gland condenser and steam ejector sized for three times the expected flow with "as new" shaft seal clearances.

15.5.1.1 The condenser shall have a steel shell, brass or cupro-nickel tubes with a nominal wall thickness of not less than 1.25 mm (0.050 in.) and a diameter of at least 15 mm ($^5/_8$ in.), and fixed tube sheets with water on the tube side. U-tubes shall not be used. The water side (tube side) shall conform to the requirements of 6.1.13. The shell side shall be designed for both full vacuum and gauge pressure of 500 kPa (75 psi).

15.5.1.2 The steam ejector shall have a steel body and a replaceable stainless steel steam nozzle.

NOTE General piping arrangements may require flow regulation valves in leak-off piping. These valves may be either specified by the user or required by the vendor.

● **15.5.2** If specified, a vacuum pump shall be provided in place of a steam ejector.

15.6 Insulation and Jacketing

15.6.1 Unless otherwise specified, the vendor shall provide thermal insulation for proper operation and for personnel protection. Exposed surfaces in personnel access areas shall not exceed a temperature of 60 °C (140 °F). Turbine casing and components shall be insulated with removable blanket type insulation.

15.6.2 Blanket insulation shall be designed so that routine maintenance may take place without damage being done to the insulation

15.6.3 Insulation shall be oil resistant and shall not contain asbestos.

15.6.4 If purchaser supplies turbine insulation, the vendor shall advise the purchaser of the expected surface temperature of the casing and any special requirements.

NOTE ISO 13732:2006, *Ergonomics of the thermal environment* explains the method for the assessment of responses to contact with surfaces.

15.7 Enclosures

15.7.1 General

● **15.7.1.1** If specified, suitable enclosure(s) shall be provided to meet purchaser's acoustical, weatherproofing, safety, and/or fire protection requirements. Enclosure(s) shall be designed to ensure the package can meet the maintenance, operation, and service life requirements. An enclosure system shall consist of the following:

a) an enclosure surrounding the steam turbine and/or driven equipment;

b) an enclosure ventilation;

c) a fire protection system including enclosure isolation devices.

15.7.1.2 Enclosures shall be designed to permit on-site maintenance. The degree of enclosure disassembly and/or access for maintenance shall be stated in the proposal.

15.7.1.3 Removable roof sections, side panels, or hinged bulkhead walls shall be provided for heavy maintenance. Construction of maintenance access ways shall permit return to the original condition. Caulking of removable portions for weatherproofing is not acceptable.

15.7.1.4 Access doors and/or manways shall be provided for routine maintenance and inspection. The sealing devices utilized around the perimeter of these access ways shall be designed to withstand normal use without loss of sealing function.

15.7.1.5 Conduits, fire prevention systems, gas detection, etc., shall not be attached to the underside of the roof or any other panels that are required to be removed for maintenance.

15.7.1.6 The enclosure shall have a minimum of two access doors. The doors shall be located on opposite walls from each other with free access. A window shall be supplied in each access door. Each window shall be double paned wire reinforced glass with a dead air space between panes.

15.7.1.7 The access doors shall have quick egress mechanism.

15.7.1.8 Unless otherwise specified, lighting for general observation is to be provided within the enclosure. Lights are to be operated by three-way switches located inside the enclosure at the access doors.

15.7.1.9 The enclosure shall be provided with a fan driven forced ventilation and purging air system designed to provide 100 % of the ventilation and purging load in the most severe climatic/load conditions. The purchaser will specify fan system redundancy requirements and whether positive or negative pressure is required.

15.7.1.10 Ventilation system shall be designed to maintain a safe inside enclosure temperature for personnel access.

15.7.1.10.1 Ventilation system will include air filtration and/or silencing equipment as required by the specified operating site climatic or operational conditions.

15.7.1.10.2 The ventilation system shall be designed to handle all specified site climatic or operational conditions.

15.7.1.10.3 Ventilation flow shall enter and exit the enclosure via port(s). Each port shall be equipped with a fire suppression medium damper and a minimum of one back flow damper within each supplied system. The purchaser will specify if additional ventilation ducting is required.

15.7.1.10.4 Unless otherwise specified, a UPS-powered fan shall be provided if cool down ventilation is required to prevent damage to the turbine, auxiliary systems, or instrumentation within the enclosure.

15.7.2 Weatherproofing

15.7.2.1 The turbine unit shall be adequate for the degree of weather exposure and for the site and atmospheric conditions specified. For outdoor installations with or without roofs, turbine units and auxiliaries shall be suitable to accommodate the specified site conditions.

15.7.2.2 Moisture buildup and corrosion on panel materials shall be minimized. Water or dust leakage through the panel walls or roof seams is unacceptable.

15.7.2.3 Materials of construction for panels shall be resistant to moisture, fire, insects, vermin, and oil wicking.

15.7.3 Fire Protection

15.7.3.1 A fire protection system shall be furnished if an enclosure is specified by the purchaser or furnished by the vendor. The system shall consist as a minimum of a fire suppression system and a fire detection system.

- **15.7.3.2** The fire suppression system shall be designed in accordance with the applicable NFPA standard including NFPA 2001 for clean agent extinguishing systems, NFPA 750 for water mist systems, and NFPA 12 for carbon dioxide extinguishing systems. The purchaser will specify any special design considerations to be included in the suppression system, including the specific fire suppression medium.

15.7.3.3 The primary method of actuation of the suppression system shall be automatic. A manual actuation system is also required. A manual release station shall be remote and located externally to the enclosure. Provisions shall be made for exercising the fire detection and protection system without discharging the fire suppression medium.

15.7.3.4 The fire detection system shall be designed in accordance with NFPA 72. Thermal detection shall be considered the minimum level of detection.

● **15.7.3.5** If specified, additional levels of detection, such as optical, shall be provided.

15.7.3.6 All fire suppression and detection devices utilized within the enclosure shall be designed to operate throughout the entire range of operational service conditions encountered within the enclosure.

15.7.4 Acoustical Treatment

15.7.4.1 If vendor furnished acoustical treatment is specified, the control of the SPL of all equipment furnished shall be a joint effort of the purchaser and the vendor. The purchaser and the vendor shall agree on the acceptance criteria and methods of compliance.

15.7.4.2 The acoustical treatment furnished by the vendor shall conform to the maximum allowable SPL specified by the purchaser.

15.7.4.3 Sound enclosures shall be in accordance with NFPA 497.

15.7.4.4 When a sound enclosure is provided over a steam turbine, the turbine supplier shall not provide any sentinel valves or relief valves that have the potential to discharge steam into the enclosure.

15.8 Turning Gear

● **15.8.1** A turning gear shall be provided if specified by the purchaser or required by the vendor.

NOTE The need for a turning gear is typically determined by the bearing span and the rotor's vulnerability to temporary bow during shutdown.

15.8.2 Energizing power operated turning gear shall be possible only after lube oil pressure has been established.

15.8.3 The turning gear shall automatically disengage when the rotor accelerates during start-up.

15.8.4 Engagement of the turning gear on shutdown before the rotor has come to a stop shall be positively prevented if this could damage the turning device or the steam turbine.

● **15.8.5** The type of turning device shall be specified. It may be driven by a steam turbine, electrical motor, hydraulic motor, or pneumatic motor. Provision shall be made to permit manual operation of the turning gear.

15.8.6 The turning-gear rotational speed and torque shall be agreed upon by the purchaser and the vendor. Consideration shall be given to duration of use, minimum speed required for the turbine and driven equipment, and the type of lube oil supply.

● **15.8.7** If specified, a turning gear operating station with associated control features, as detailed by the purchaser, shall be provided.

15.8.8 Automatic engagement shall not occur in the event of reverse rotation following a trip. Turning gear shall be designed to automatically disengage to prevent damage during reverse rotation events.

15.9 Special Tools

15.9.1 When 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 mult-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between purchaser and vendor. These special tools shall be used, and their use demonstrated, during shop assembly and post-test disassembly of the equipment.

15.9.2 When 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 metal tagged to indicate its intended use.

15.9.3 Unless otherwise specified, when spreader beams or other special lifting devices are required for installation or maintenance, the vendor shall provide them. The purchaser shall specify whether these devices shall be provided on loan or for permanent retention by the owner. Special lifting devices shall be marked with SWL.

16 Inspection, Testing, and Preparation for Shipment

16.1 General

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

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

16.1.3 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed. For mechanical running or performance tests, this requires written notification of a successful preliminary test. The purchaser should expect to be in the factory longer for an observed test than for a witnessed test.

● **16.1.4** The purchaser shall specify the extent of his/her participation in the inspection and testing and the amount of advance notification he/her requires.

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

16.1.6 Equipment, materials, and utilities for the specified inspection and tests shall be provided by the vendor.

● **16.1.7** If specified, the purchaser’s representative, the vendor’s representative, or both shall indicate compliance with this standard by initialing, dating and submitting a completed checklist to the purchaser before shipment. For a typical inspector’s checklist, see Annex H. Inspector checklist in Annex H shall be completed, initialed, and dated by vendor, and submitted to purchaser before shipment.

16.1.8 The purchaser’s representative shall have access to the vendor’s quality-control program for review.

16.2 Inspection

16.2.1 General

16.2.1.1 The vendor shall keep the following data available for at least 20 years:

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

b) specifications for all purchased items;

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

d) test data to verify that the requirements of the specification have been met;

e) results of quality-control tests and inspections;

f) final-assembly maintenance and running clearances;

g) details of all major repairs (see 7.5.3, 11.2.3.3, and 11.3.3);

h) other data specified by the purchaser or required by applicable codes and regulations (see 17.3).

NOTE 1 Test data applies to such tests as hydro and mechanical running, as well as NDE results.

NOTE 2 A summary of typical component inspections is given in Annex G.

16.2.1.2 Pressure-containing parts shall not be painted until the specified pressure testing of the parts is completed.

● **16.2.1.3** In addition to the requirements of 11.3.4 and the ASTM material specifications, the purchaser shall identify:

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

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

NOTE 1 Inspection of pressure-containing components is covered in 7.5.

NOTE 2 ASTM material specifications contain mandated and supplemental inspections.

NOTE 3 Review of quality assurance and testing are items on the coordination meeting agenda in 17.1.3.

16.2.2 Material Inspection of Nonpressure Casing Parts

16.2.2.1 General

● **16.2.2.1.1** NDE shall be performed as required by the material specification. When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the recommended practices in 16.2.2.2 through 16.2.2.5 shall apply unless other corresponding procedures and acceptance criteria have been specified. Cast iron may be inspected only in accordance with 16.2.2.4 and/or 16.2.2.5. Welds, cast steel, and wrought material shall be inspected in accordance with 16.2.2.2 through 16.2.2.5. Radiography should normally be considered for steam gauge pressures exceeding 8600 kPa (1250 psi) or steam temperatures exceeding 510 °C (950 °F).

NOTE The material inspection of pressure-containing parts is covered in 7.5.

16.2.2.1.2 These recommended practices describe examination techniques that are applicable to great varieties of sizes and shapes of materials and widely varying examination requirements. Since the specification for the actual component being inspected depends on metallurgy, component configuration, and method of manufacture, specific procedures and acceptance standards for the application shall be covered by written standards, developed by the manufacturer for the specific application.

16.2.2.1.3 Acceptance standards for 16.2.2.2 through 16.2.2.5 shall be agreed upon between the purchaser and vendor. The user may wish to consult and use as a guide API 687, First Edition, Chapter 1, Section 3, Table 1.8-1.

16.2.2.2 Radiography

16.2.2.2.1 Radiography shall be in accordance with ASTM E94.

16.2.2.3 Ultrasonic Inspection

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

16.2.2.4 Magnetic Particle Inspection

16.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709. To prevent buildup of potential voltage in the equipment, all components shall be demagnetized to the free air gauss levels in Table 6 when measured with a calibrated Hall effect probe.

Table 6—Maximum Allowable Free Air Gauss Levels

Gauss Level	Component
±2 Gauss	Bearing and seal assemblies including all components
±4 Gauss	Casing and all stationary components except bearing and seal assemblies
±2 Gauss	Shaft and all rotating components
NOTE The free air gauss level is measured while suspending the component from a nonconductive strap with no influence from stray magnetic fields.	

16.2.2.5 Liquid Penetrant Inspection

16.2.2.5.1 Liquid penetrant inspection shall be based upon the procedures of ASTM E165 and ASTM E1417.

16.2.2.6 Forgings used for turbine shafts, disks, and rotors with integrally forged disks shall be inspected by ultrasonic methods in accordance with ASTM A418.

NOTE Guidance concerning performing shot peening after magnetic particle and penetrant testing is provided in AMS-S-13165 and ASME *BPVC*, Section V, Article 24, SE-165.

16.2.2.7 Unless otherwise specified, a heat stability check shall be performed on the turbine shaft or rotor forging in accordance with ASTM A472.

● **16.2.2.8** If specified, details of procedures and acceptance limits for thermal stability tests on rotors shall be supplied.

16.2.2.9 Steel castings shall be examined visually in accordance with applicable ASTM specifications. MSS SP-55 shall be used to define acceptable surface discontinuities and finish.

16.2.3 Mechanical Inspection

16.2.3.1 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.

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

● **16.2.3.3** If specified, the purchaser may inspect for cleanliness of the equipment, all piping, and appurtenances before installation of nozzle blocks and steam-chest covers, final assembly of piping, or closure of openings.

● **16.2.3.4** If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation, and witnessing of the testing shall be agreed by the purchaser and the vendor.

16.3 Testing

16.3.1 General

16.3.1.1 Equipment shall be tested in accordance with 16.3.2 and 16.3.3. Other tests that may be specified by the purchaser are described in 16.3.4.

16.3.1.2 At least six weeks before the first scheduled mechanical running test, the vendor shall submit to the purchaser for his/her review and comment, detailed procedures for all running tests, and all specified optional tests (16.3.4), including acceptance criteria for all monitored parameters.

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

16.3.2 Casing Pressure Hydro Tests

16.3.2.1 General

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

16.3.2.1.2 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 transition temperature is the highest temperature at which a material experiences complete brittle fracture, without appreciable plastic deformation.

16.3.2.1.3 The vendor shall define test procedures for turbines with double shell construction.

16.3.2.2 Casing Integrity Test

16.3.2.2.1 All pressure-containing parts shall be hydro pressure tested to prove casing integrity with liquid at a gauge pressure of at least 1.5 times the maximum allowable working pressure but not less than 140 kPa (20 psi). See 3.23.

16.3.2.2.2 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 hydro 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 be determined in accordance with 7.1.2. The pressure thus obtained shall then be the minimum pressure at which the hydro test shall be performed. The datasheets shall list actual hydro test pressures. Applicability of this requirement to the material being tested shall be verified before pressure test, as the properties of many grades of steel do not change appreciably at temperatures up to 200 °C (400 °F).

16.3.2.2.3 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The pressure casing integrity hydro test shall be considered satisfactory when neither leaks nor seepage through the casing is observed for a minimum of 30 min. Large, heavy castings may require a longer testing period to be agreed upon by the purchaser and the vendor. Seepage past internal test closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

NOTE The purpose of the pressure hydro test is to prove pressure casing integrity and not to prove joint sealing.

16.3.2.2.4 Use of a sealant compound or gasket on the casing joints is acceptable during the casing integrity hydro test.

16.3.2.3 Casing Joint Leakage Test

A hydro test for casing joint leakage shall be performed. The hydro test pressure shall be 1.5 times the maximum allowable working pressure in that pressure zone. Temperature corrections as specified in 16.3.2.2.2 are not required for this test. This test should be performed after the casing hydro integrity test. Gaskets shall not be used at the casing joint for this test. Suitable joint compound may be used (see 7.1.6). The test shall be considered satisfactory when neither leaks nor seepage through the casing joint is observed for a minimum of 30 min. The casing joint leakage test may be combined with the casing hydro integrity test, provided casing joint gaskets are not used.

16.3.3 Mechanical Running Test

16.3.3.1 The requirements of Items a) to j), as follows, shall be met before the mechanical running test is performed.

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

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

c) Test-stand oil filtration shall be 10 μm nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of API 614 before any test is started.

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.

f) The mechanical running test shall be performed with the contract half coupling and a coupling mass simulator, or moment simulator, in accordance with API 671.

g) All contract vibration probes, cables, oscillator-demodulators, and accelerometers shall be used during the test.

h) Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting revolutions per minute, peak-to-peak displacement and phase angle (x-y-y'). Presentation of vibration displacement and phase marker shall also be by oscilloscope.

i) The vibration characteristics determined by the use of instrumentation specified in Items g) and h) shall serve as the basis for acceptance or rejection of the machine.

j) If external housing vibration test values are specified, vibration data (minimum and maximum values and phase angles) shall be measured vertically and horizontally transverse to each bearing centerline using shop instrumentation.

16.3.3.2 Unless otherwise specified, operation of the control systems shall be demonstrated and the mechanical running test of the steam turbine shall be conducted as specified in a) to f), as follows.

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

a) Operate the equipment at speed increments of approximately 10 % from zero to the maximum continuous speed (avoiding any resonant speeds) and run at maximum continuous speed until bearings, lube oil temperatures, and shaft vibrations have stabilized.

b) Increase the speed to trip speed and run the equipment for a minimum of 15 min.

c) Check overspeed trip devices and adjust them until values within 1 % of the nominal trip setting are attained. Mechanical overspeed devices, when supplied, shall attain three consecutive nontrending trip values that meet this criterion.

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

e) Record data for governors such that it includes at least the sensitivity and linearity of relationship between speed and control signal, and, for adjustable governors, the response speed range.

f) Run the turbine continuously at the maximum continuous speed for at least four hours.

16.3.3.3 During the mechanical running test, the following requirements shall be met.

a) The mechanical operation of all equipment being tested, including all casing joints and connections, and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 9.7.8 and shall be recorded throughout the operating speed range.

b) While the equipment is operating at maximum continuous speed and at other speeds and/or load that may have been specified in the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous. As a minimum, this data shall cover a frequency range from 0.05 times to 8 times the maximum continuous speed. If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 9.7.8, the purchaser and the vendor shall agree on requirements for any additional testing and on the equipment's acceptability.

c) The mechanical running test shall verify that lateral critical speeds conform to the requirements of 9.2 and 9.3. Any non-critically-damped critical speed below the trip speed shall be determined during the mechanical running test.

d) Shop verification of the unbalanced response analysis shall be performed in accordance with 9.3.

● e) Real-time vibration data, as agreed upon by the purchaser and vendor, shall be recorded and a copy provided to the purchaser.

● f) Plots showing synchronous vibration amplitude and phase angle versus speed for deceleration shall be made before and after the four-hour run. Plots shall be made of both the filtered (one for each revolution) and unfiltered vibration levels. If specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be from the specified trip speed to 400 r/min.

g) During the four-hour test, lube oil inlet pressures and temperatures shall be varied through the range specified in the steam turbine operating manual. The lube oil and control oil temperatures shall be held for at least 30 min. at a value corresponding to the minimum allowable viscosity and 30 min. at a value corresponding to maximum allowable viscosity. Under both conditions, shaft vibration shall be measured in accordance with 16.3.3.3 b), checking in particular for oil film instabilities.

16.3.3.4 Unless otherwise specified, the following requirements 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 if dismantling of the case to replace or modify other parts, is required to correct mechanical deficiencies, the initial test shall not be acceptable. Final shop tests shall be run after these deficiencies are corrected.

c) When spare rotors are ordered to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with this standard. Spare stators, if furnished, shall be used for the mechanical run test of the spare rotor.

16.3.4 Additional Tests and Inspections

16.3.4.1 General

The purchaser shall specify in the enquiry or in the order whether any of the shop tests specified in 16.3.4.2 to 16.3.4.11 shall be performed.

16.3.4.2 Performance Test

● If specified, the machine shall be tested in accordance with the methodology and acceptance criteria agreed between the purchaser and the vendor. Vibration levels shall be measured and recorded during this test, as specified in 16.3.3.1 and 16.3.3.2. ASME Performance Test Code (PTC) 6 and IEC 60953 contain useful steam turbine testing information.

16.3.4.3 Complete Unit Test

● If specified, components such as compressors, gears, drivers, and auxiliaries, which make up a complete unit, shall be tested together. By agreement, this test may incorporate the mechanical running test.

16.3.4.4 Auxiliary Equipment Test

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

16.3.4.5 Post-test Internal Inspection of Casing

● If specified, the steam turbine shall be dismantled, inspected and reassembled after satisfactory completion of the mechanical running test.

The merits of post-test internal inspection of casing should be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

16.3.4.6 Factory Overspeed Shutdown Systems Test

The vendor shall verify that the actual response time of the overspeed shutdown system does not exceed the response time used in the overspeed calculation for the maximum speed excursions specified in 8.1.1. When the vendor does not supply all system components, the response of components not supplied shall be agreed and shall be incorporated in the total response time.

● 16.3.4.7 Field System Overspeed Shutdown Systems Response Test

If specified, after complete field installation, the vendor or responsible party is required to provide purchaser with actual measured total shutdown system response times for at least four overspeed trip events as proof that the total system response time meets 8.1.1 and 12.3.1.7 requirements.

NOTE 1 Total shutdown system response time consists of the signal delay time and the valve closure time. The signal delay time is the period of time between when an overspeed trip condition was sensed and the time the trip valve(s) starts to close. The valve closure time is the time that the valve needs to travel from fully open to fully closed. This test has to prove that both signal delay time and valve closure time are adequate to meet the requirements of 8.1.1 and 12.3.1.7.

NOTE 2 This response time test is typically initially a nonrunning test. The test can also be repeated with the turbine hot.

16.3.4.8 Spare Parts Test

● Spare parts such as couplings, gears, diaphragms, bearings, and seals shall be tested as specified by the purchaser.

See 16.3.3.4 c) for a mechanical test of the spare rotor.

16.3.4.9 Inspection of Hub/Shaft Fit for Hydraulically Mounted Couplings

● If specified, after the running tests, the shrink fit of hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.

16.3.4.10 Trip Valve Test

Complete valve assembly shall be tested by the valve vendor in its specified orientation and tripped closed from the full open position. Travel versus time shall be recorded. The trip time shall not exceed the required trip time.

16.3.4.11 Governor System Response Test Under Load

● If a load test is performed at a specific operating point, the response time of the turbine governing system shall be continuously recorded to confirm compliance with the requirements of Section 12. During site testing, this is done by recording the control response in amplitude and time period to comply with 12.2.6 requirements.

16.3.4.12 Sound Level Test

● If specified, the sound level test shall be performed in accordance with ISO 3744 or other agreed upon standard.

SPLs may be converted into sound power levels in accordance with ISO 10494.

16.4 Preparation for Shipment

● **16.4.1** Equipment shall be prepared for the type of shipment specified, including blocking of the rotor when necessary. Blocked rotors shall be identified by means of corrosion-resistant tags attached with stainless steel wire. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser shall consult with the vendor regarding the recommended procedures to be followed. Vendor’s long-term storage package (more than one year) shall be included in the proposal as an alternative.

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

16.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in Items a) to n), as follows.

a) Except for machined surfaces, all exterior surfaces that may 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. Austenitic stainless steels typically are not painted, shall not be coated, and shall not be exposed to inorganic zinc primers, zinc bearing paints, or zinc bearing compounds.

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

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

d) Internal surfaces of bearing housings and carbon steel oil systems' 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 (tagged) 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.

g) Turbines supplied without self-supporting baseplates shall be bolted to a shipping skid formed of heavy timbers suitable for sling-lift or forklift truck handling. Larger turbines shall have supports as required by the type of transportation and handling.

h) Lifting points, lifting lugs, and the center of gravity shall be clearly identified on the equipment package. The vendor shall provide the recommended lifting arrangement.

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

● j) If a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 10 years. The rotor shall be crated for domestic or export shipment, as specified. Lead sheeting at least 3 mm ($^{1}/_{8}$ in.) thick or a purchaser-approved equivalent shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals. Unless otherwise specified, the rotor shall be prepared for vertical storage. It shall be supported from its coupling end with a fixture designed to support 1.5 times the rotor's mass without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation, and maintenance manuals. If specified on the datasheets, the spare rotor shall be crated in a metal container, which is suitable for transportation and storage. Before applying the rust preventative, the spare rotor(s) shall be cleaned thoroughly to remove all fingerprints from polished surfaces. Fingerprint remover shall be used as necessary. The identification attached to the spare rotor shall include the manufacturer's serial number and the statement: SPARE ROTATING ASSEMBLY FOR TURBINE NO.__.

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

l) Where VPI or silica gel crystals in bags are installed in large cavities, either for inhibiting corrosion or absorbing moisture, respectively, they shall be in an accessible area for easy removal. The bags shall be attached with stainless steel wire and their locations indicated with corrosion-resistant tags also fixed with stainless steel wire.

m) Separately shipped parts and spare parts, after treatment for rust prevention, shall be wrapped in VPI paper and packed individually into sturdy boxes. Identification tags shall be attached to each part as well as to the outside of each box. Spare parts shall be crated separately from parts needed for initial installation.

● n) If specified, internal inspection shall be performed. During the inspection, the interior of the equipment shall be clean; free from scale, welding spatter and foreign objects; and sprayed or flushed with rust preventative that can be removed with solvent. The rust preventative shall be applied through all openings while the rotor is rotated.

16.4.4 Auxiliary piping connections furnished on the purchased equipment shall be match-marked (for ease of reassembly), and impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

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

16.4.6 One copy of the manufacturer's installation instructions shall be packed and shipped with the turbine.

16.4.7 Connections on auxiliary piping, removed for shipment, shall be tagged and match-marked for ease of reassembly.

16.4.8 The fit-up and assembly of machine-mounted piping shall be completed in the vendor's shop prior to shipment, to confirm fit-up.

16.4.9 Special care shall be taken when shipping the steam turbine with chemicals such as:

— insulating oils,

— corrosion inhibitors,

— antifreeze solutions,

— desiccants,

— chemical substances,

— hydrocarbon substances.

Shipping requirements include the following.

a) Chemicals shipped shall have a material safety datasheet (MSDS). Before shipment, a current MSDS shall be forwarded to user's facility for each substance shipped in or with equipment.

b) Equipment or materials that contain or are coated with any of the above listed chemicals shall be prominently tagged at openings to indicate nature of contents and precautions for shipping, storage, and handling.

c) MSDS copies shall be affixed in protective envelopes to outside of shipment.

d) MSDS(s) shall fully comply with local regulations for MSDS preparation and shall include statement that substance is considered hazardous by regulation.

e) If any products are exempt from regulation, a statement to that effect shall be included.

17 Vendor's Information

17.1 General

17.1.1 The information to be furnished by the vendor is specified in 17.2 and 17.3. The vendor shall complete and forward a vendor drawing and data requirements form (see typical form in Annex J) or purchaser's equivalent to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

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

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

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

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

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

17.1.3 A coordination meeting shall be held, preferably at the vendor's plant, within 4-6 weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum shall include a review of the following items:

a) the purchase order, scope of supply, unit responsibility, sub-vendor items and lines of communications;

b) the datasheets;

c) applicable specifications and previously agreed exceptions;

d) schedules for the transmittal of data, production and testing;

e) the quality assurance program and procedures;

f) inspection, expediting and testing;

g) schematics and bills of material for auxiliary systems;

h) the physical orientation of the equipment, piping and auxiliary systems, including access for operation and maintenance;

i) coupling selection and rating;

j) thrust and journal bearing sizing, estimated loading and specific configurations;

k) the preliminary rotor dynamic analyses (lateral, torsional and transient torsional, as required);

l) equipment performance, alternate operating conditions, start-up, shutdown, and any operating limitations;

m) instrumentation and controls;

n) scope and details of vibration analysis;

o) identification of items requiring design reviews;

p) inspection, related acceptance criteria, and testing;

q) expediting;

r) other technical items.

17.2 Proposals

17.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. The proposal shall include, as a minimum, the data specified in 17.2.2 to 17.2.4, and a specific statement that the equipment and all its components and auxiliaries are in strict accordance with this standard. If the equipment or any of its components or auxiliaries is not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 17.1.2.

17.2.2 Drawings

The drawings indicated on the vendor drawing and data requirements form (VDDR form, see Annex I) shall be included in the proposal. As a minimum, the following data shall be included.

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

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

c) Schematics of all auxiliary systems, including the steam, lube oil, control, and alarm and shutdown systems. Bills of material shall be included.

d) Sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries. This information may be included on the drawings specified in 17.2.2 a).

e) Detail drawing of lifting lugs or any other lifting point including dimension data and load rating.

f) 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.

17.2.3 Technical Data

The following data shall be included in the proposal.

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

b) The predicted noise data (see 6.1.17).

c) The VDDR form, indicating the schedule according to which the vendor agrees to transmit all the data specified.

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

e) A priced list of spare parts recommended for start-up, normal maintenance purposes, and capital spares (i.e. rotor, guide blade carriers or diaphragms, etc.). The pricing for spare rotors shall include all applicable mechanical testing.

f) A list of the special tools furnished for maintenance.

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

h) A complete tabulation of utility requirements, e.g. steam, water, electricity, air, and 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 identified as such.)

i) A description of any optional or additional tests and inspection procedures for materials, in accordance with 16.3.4.

j) A description of any special requirements, whether specified in the purchaser's inquiry and in accordance with 11.1.2 and 15.4.

k) A list of machines similar to the proposed machine(s) that have been installed and are 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) The expected output power at normal steam conditions and rated speed with governor control valves fully open.

n) Approximate potential maximum power output of the unit under normal steam conditions and at normal speed that could be obtained by field modification—the required field modifications shall be described in general (e.g. valve, nozzle, diaphragm, or blade changes with no changes to the rotor or casing).

o) A list of all relief valves in accordance with 15.4, including size and set pressure—relief valves furnished by the vendor shall also be specified, with valve manufacturer and model data provided.

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

q) The types of fasteners (e.g. SI or USC) used in equipment, including auxiliaries, in the vendor's scope of supply.

r) Exceptions and clarifications to the purchaser's specifications. The vendor's proposal shall be in accordance with purchaser's specifications and datasheets. If the vendor is unable to comply with any requirements of the purchaser's specifications, the proposal shall clearly state the reasons for noncompliance, any exceptions and clarifications. The vendor may propose an alternative, which will meet the technical requirements in a satisfactory and reliable manner, for approval.

17.2.4 Curves

The vendor shall provide complete performance curves to encompass the map of operations, with any limitations indicated thereon. The curves shall include those indicated by the purchaser on the VDDR form.

17.3 Contract Data

17.3.1 General

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

17.3.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, identification data specified in 17.1.2, revision number and date, and title. Similar information shall be provided on all other documents including sub-vendor items.

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

17.3.1.4 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of each item listed. This list shall cross-reference data with the VDDR form in the purchase order.

17.3.2 Drawings and Technical Data

17.3.2.1 The drawings and data furnished by the vendor shall contain sufficient information so that, together with the manuals specified in 17.3.5, 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 (see 17.1.1), and shall satisfy the applicable detailed descriptions in Annex I.

17.3.2.2 Material certifications shall be provided for the turbine rotor shaft, buckets, shrouds, and major casing components.

17.3.2.3 PMI records shall be provided when PMI is specified for applicable alloy steel components.

17.3.3 Progress Reports

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

NOTE Refer to the description of Item pp) in Annex I for content of these reports.

17.3.4 Parts Lists and Recommended Spares

17.3.4.1 The vendor shall submit complete parts lists for all equipment and accessories supplied. These lists shall include part names and manufacturers' unique part numbers. 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 finished 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.

17.3.4.2 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 part. These should include spare parts recommendations of sub-suppliers that were not available for inclusion in the vendor's original proposal. The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up.

● **17.3.4.3** If specified, a spare parts interchangeability list shall be provided when more than one turbine is being supplied (nonduplicate), or in the case where the user already operates a turbine made by the vendor at the location where the new turbine is intended.

17.3.5 Installation, Operation, Maintenance, and Technical Manuals

17.3.5.1 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 17.1.2, an index sheet, and a complete list of 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. If the order covers more than one turbine, all turbines that are not identical require separate documentation.

17.3.5.2 Installation Manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions. This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging provisions and procedures, and all installation data. All drawings and data specified in 17.2.2 and 17.2.3 that are pertinent to proper installation shall be included as part of this manual [see description of Item mm) in Annex I].

17.3.5.3 Operating and Maintenance Manual

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

17.3.5.4 Technical Data Manual

● If specified, the vendor shall provide the purchaser with a technical data manual within 30 days of completion of shop testing. [See description of Item tt) in Annex I for minimum requirements of this manual.]

Annex A
(informative)

Typical Datasheets

This annex contains typical datasheets for use by the purchaser and the vendor.

The sheets are presented in SI units (10 sheets) and USC units (10 sheets).

Unless indicated otherwise, all pressure units are gauge pressure.

	JOB NO. ______ ITEM NO. ______
	PURCHASE ORDER NO. ______
	SPECIFICATION NO. ______
SPECIAL-PURPOSE STEAM TURBINE DATASHEET SI UNITS	REVISION NO. ______ DATE ______
	PAGE 1 OF 10 BY ______

1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ▢ AS-BUILT
2 FOR ______ UNIT ______
3 SITE ______ SERIAL NUMBER ______
4 SERVICE ______ NUMBER REQUIRED ______
5 MANUFACTURER ______ MODEL ______ DRIVEN EQUIPMENT ITEM NO. ______
6 DRIVEN EQUIPMENT TYPE: ○ COMPRESSOR ○ GENERATOR ○ OTHER ______
7 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ▢ PURCHASER OR MANUFACTURER

8 **PERFORMANCE**

	OPERATING POINTS	SHAFT		INLET			INDUCTION/EXTRACTION			EXHAUST		
9, 10, 11, 12	○ ☐ AS APPLICABLE	POWER kW	SPEED r/min	FLOW kg/h	PRESS kPa	TEMP ℃ (TT)	FLOW kg/h	PRESS kPa	TEMP ℃ (TT)	PRESS kPa	TEMP ℃ (TT)	ENTHALPY kJ / kg
13	RATED											
14	NORMAL (3.35)(6.14)											
15	MINIMUM											
16												

17 ☐ STEAM RATE, kg/kW.h (3.56): ______ NORMAL ______ RATED — INDUCTION ○ CONTROLLED ○ UNCONTROLLED
18 ☐ POTENTIAL MAXIMUM POWER(3.40) — EXTRACTION ○ CONTROLLED ○ UNCONTROLLED

19 **STEAM CONDITIONS**

			▢ INLET	▢ EXHAUST	▢ EXTRACTION INDUCTION	▢ EXTRACTION INDUCTION	▢ EXTRACTION INDUCTION
20, 21							
22		MAXIMUM					
23	FLOW	NORMAL					
24	kg/h	MINIMUM					
25	PRESSURE	MAXIMUM					
26	kPa	NORMAL					
27		MINIMUM					
28		MAXIMUM					
29	TEMPERATURE	NORMAL					
30	℃ (TT)	MINIMUM					

31 **SITE AND UTILITY DATA**

32 **LOCATION:**
33 ○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR
34 ○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE
35 ○ OTHER: ______
36 ○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D
37 ○ LOW TEMPERATURE ○ CORROSIVE AGENTS
38 ○ ELECTRICAL AREA CLASSIFICATION:
39 CLASS ___ GROUP ___ DIVISION ______
40 ZONE ___ GROUP ___ TEMPERATURE RATING: ______
41 **SITE DATA:**
42 ○ ELEVATION ______ m ○ BAROM. PRESS ______ kPa
43 ○ WINTER TEMP. ______ ℃ SUMMER TEMP. ______ ℃
44 ○ REL. HUMIDITY ______ % DESIGN WET BULB ______ ℃
45 ○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES
46 ○ OTHER ______
47 **UTILITY CONDITIONS:**
48 ○ AUXILIARY STEAM: MAX NORM MIN
49 INITIAL PRESS.(kPa)) ______ ______ ______
50 INITIAL TEMPERATURE, ℃ (TT) ______ ______ ______
51 EXH. PRESS. (kPa) ______ ______ ______
52 INST. AIR (kPa): NORM ___ MIN ___ MAX ___
53 INSTRUMENT AIR DEW POINT: ℃

32 ○ **ELECTRIC:**

	DRIVERS	HEATING	INSTRUMENT/ CONTROL	ALARM/ SHUTDOWN
VOLTS				
PHASE				
HERTZ				
kW AVAILABLE				

38 ○ **COOLING WATER:**
39 INLET TEMPERATURE: ___ ℃ MAXIMUM RETURN ___ ℃
40 PRESS. NORM.: ______ kPa DESIGN ______ kPa
41 MINIMUM RETURN PRESSURE: ______ kPa
42 MAXIMUM ALLOWABLE PRESS. DROP: ______ kPa
43 WATER SOURCE ______
44 VELOCITY, m/s: MIN ______ MAX ______
45 FOULING FACTOR: ______ W/(m²K)
46 ○ **UTILITY CONSUMPTION:**
47 COOLING WATER: ______ m³/h INST. AIR ______ m³/h
48 AUX. STM: NORMAL ______ kg/h MAXIMUM ______ kg/h
49 AUX. DRIVERS: ELECTRIC ______ kW STEAM ______ kW
50 HEATER(S): ______ kW OTHER: ______

54 REMARKS: ______
55 ______

SPECIAL-PURPOSE STEAM TURBINE DATASHEET SI UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 2 OF 10 BY ______

APPLICABLE SPECIFICATIONS:

API 612, SPECIAL-PURPOSE STEAM TURBINES
○ OTHER ______
○ VENDOR HAVING UNIT RESPONSIBILITY (3.59): ______
○ GOVERNING SPECIFICATION, IF DIFFERENT: ______

NOISE SPECIFICATIONS:

○ APPLICABLE TO MACHINE:
SEE SPECIFICATION: ______
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION: ______
ACOUSTICAL TREATMENT ○ YES ○ NO
TYPE ______

CONSTRUCTION FEATURES

TURBINE TYPE ○ BACK-PRESSURE ○ CONDENSING ○ INDUCTION ○ EXTRACTION ○ OTHER

☐ SPEEDS:
MAXIMUM CONTINUOUS ______ r/min TRIP ______ r/min
MAXIMUM ALLOWABLE ______ r/min
☐ LATERAL CRITICAL SPEEDS (DAMPED) (9.2)
FIRST CRITICAL ______ r/min ______ MODE
SECOND CRITICAL ______ r/min ______ MODE
THIRD CRITICAL ______ r/min ______ MODE
FOURTH CRITICAL ______ r/min ______ MODE
☐ VIBRATION ______ µm (PEAK TO PEAK)

☐ TORSIONAL CRITICAL SPEEDS (9.6):
FIRST CRITICAL ______ r/min
SECOND CRITICAL ______ r/min
THIRD CRITICAL ______ r/min
FOURTH CRITICAL ______ r/min
○ LATERAL ANALYSIS REPORT REQUIRED
○ INDIVIDUAL BODY ○ TRAIN
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED
○ TRAIN TORSIONAL PERFORMED BY

☐ CASINGS, NOZZLES & DIAPHRAGMS

☐ MAWP (3.23)(7.1.3)
INLET SECTION ______ EXH. SECTION ______ (kPa)
INDUCTION / EXTRACT. SECTION ______ (kPa)
OTHER ______ (kPa)
☐ MAX OPERATING TEMP. (3.22)(3.27)
INLET SECTION ______ °C EXHAUST SECTION ______ °C
INDUCTION / EXTRACTION SECTION ______ °C
○ MINIMUM DESIGN METAL TEMPERATURE (11.1.15) ______ °C
○ RELIEF VALVE SETTING INLET ______ (kPa) ______ (kPa)
EXTRACTION ______ (kPa) OTHER ______ (kPa)

☐ HYDRO TEST PRESSURE (16.3.2.2)
HP CASING ______ MID CASING ______ (kPa)
EXHAUST CASING ______ OTHER ______ (kPa)
○ WELDED NOZZLE RING (7.3.1) NOZZLE RING ______ % ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST ☐ WELDED
(7.3.2) ☐ OTHER ______
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	☐ SIZE	☐ FACING	○ POSTION	○ FLANGED OR STUDDED (7.2.1)(7.2.3)	○ MATING FLG. & GASKET BY VENDOR [7.2.8)]	☐ MAXIMUM STEAM FLOW kg/h	☐ MINIMUM STEAM FLOW kg/h
INLET							
EXHAUST							
EXTRACTION							
INDUCTION							

AUX. SCRWD. PIPE CONN.: ○ TAPERED ○ STRAIGHT ○ MAIN CASING JOINT STUDS / NUTS DESIGNED FOR HYD. TENSIONING [7.1.15 f)]

☐ ALLOWABLE FORCES & MOMENTS

	INLET		EXHAUST		EXTRACT. / INDUCT.	
	FORCE	MOMENT	FORCE	MOMENT	FORCE	MOMENT
	N	N-m	N	N-m	N	N-m
PARALLEL TO SHAFT						
VERTICAL						
HORZ. 90°						

ROTATION: (VIEWED FROM INLET END)

○ CW ○ CCW

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MATERIALS-CASINGS & APPURTENANCES:

- ☐ HIGH PRESSURE CASING ______
- ☐ MID PRESSURE CASING ______
- ☐ EXHAUST CASING ______
- ☐ STEAM CHEST ______
- ☐ NOZZLE RING ______
- ○ STEAM CONTAMINANTS (11.1.6) ______
- ○ STEAM PATH COMPONENTS < HRC 22 (11.1.9)
- ☐ DIAPHRAGM/BLADE CARRIERS ______
- ☐ DIAPHRAGM NOZZLES ______
- ☐ OTHER ______

ROTATING ELEMENTS (8)

SHAFT TYPE:

- ☐ INTEGRAL WHEELS ☐ BUILT-UP (8.1.2) ☐ COMBINATION
- ☐ DOUBLE EXTENDED
- ☐ NUMBER OF STAGES ______ BEARING SPAN ______ mm
- ☐ SHAFT MATERIAL ______

BLADES(BUCKETS): ☐ MAX TIP SPEED ______ m/s

- ☐ FINAL STAGE BLADE LENGTH ______ mm MAX. ______ mm

☐ SHAFT ENDS: DIAMETER @ COUPLING ______ mm
- ○ STRAIGHT ○ TAPER ______ mm/m
- ○ KEYED ○ SINGLE ○ DOUBLE
- ○ HYDRAULIC FIT ○ INTEGRAL FLANGE
- ○ FIELD BALANCING PROVISIONS REQUIRED (8.1.4)
- ☐ DESCRIPTION OF FIELD BALANCING PROVISIONS: ______

REMARKS: ______

	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE
☐ WHEEL MATERIAL							
☐ BLADE MATERIAL							
☐ BLADE ROOT TYPE							
☐ CLOSURE PIECE TYPE							
☐ TIE WIRE MATERIAL							
☐ SHROUD MATERIAL							
☐ SHROUD ATTACH.							
☐ PITCH DIAMETER, mm.							
☐ BLADE HEIGHT, mm.							
☐ BLADE TYPE							
☐ ______							
☐ ______							

SHAFT SEALS (10.6)

	INLET	EXHAUST
☐ MAX. SEAL PRESSURE, kPa		
☐ STEAM LEAKAGE, kg/h		
☐ AIR LEAKAGE, m^3/h (std cond.)		
☐ SHAFT DIA. @ SEAL, mm		
☐ STATIONARY LABY. TYPE		
☐ ROTATING LABY. TYPE		
☐ MATERIAL		
☐		
☐		
☐ ______		

TYPE: ○ LABYRINTH (10.6.1) ○ OTHER ______
MATERIAL: ______

INTERSTAGE SEALS (10.6.2):

TYPE: ○ LABYRINTH
○ OTHER ______
MATERIAL: ______

REMARKS: ______

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BEARINGS AND BEARING HOUSINGS

RADIAL (10.1)(10.2)

	INLET	EXHAUST
☐ TYPE		
☐ MANUFACTURER		
☐ LENGTH (mm)		
☐ SHAFT DIAMETER (mm)		
☐ UNIT LOAD (ACT/ALLOW), N		
☐ BASE MATERIAL		
☐ BABBIT THICKNESS (mm)		
☐ NUMBER OF PADS		
☐ LOAD: BETWEEN/ON PAD		
☐ PIVOT: CENTER/OFFSET %		
☐ ______		
☐ ______		

THRUST (10.1)(10.3)

	ACTIVE	INACTIVE
☐ TYPE		
☐ MANUFACTURER		
☐ UNIT LOADING MAX. (MPa)		
☐ UNIT LOAD ULTIMATE (MPa)		
☐ NUMBER OF PADS		
☐ AREA (mm²)		
☐ PIVOT: CENTER / OFFSET, %		
☐ PAD BASE MATERIAL		

LUBRICATION: ○ FLOODED ○ DIRECTED
THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE

BEARING TEMPERATURE DEVICES:

○ THERMOCOUPLES ○ TYPE ______
○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______
○ RESISTANCE TEMPERATURE DETECTORS
○ RESISTANCE MATERIAL ______ ☐ ______ ohm
○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______ MFR
○ LOCATION-JOURNAL BEARING
TOTAL ______ LOCATION ______
SCALE RANGE ______ ALARM SET @ ______ °C
SHUTDOWN SET @ ______ °C DELAY ______ s
○ LOCATION-THRUST BEARING
ACTIVE SIDE
TOTAL ______ LOCATION ______
INACTIVE SIDE
TOTAL ______ ______ LOCATION ______
SCALE RANGE ______ ALARM SET @ ______ °C
SHUTDOWN SET @ ______ °C DELAY ______ s
○ MONITOR SUPPLIED BY: ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______

VIBRATION DETECTORS:

○ TYPE ______ ☐ MODEL ______
○ MANUFACTURER ______ ______
○ NUMBER AT EACH SHAFT BRG ______ TOTAL NUMBER ______
MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ ALARM ☐ SET @ ______ µm
○ SHUTDOWN: ☐ SET @ ______ µm ○ DELAY ______ s

AXIAL POSITION DETECTORS:

☐ TYPE ______ ☐ MODEL ______
○ MFR ______ ○ NUMBER REQUIRED ______
MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ ALARM ______ ☐ SET @ ______ µm
○ SHUTDOWN ☐ SET @ ______ µm ○ DELAY ______ s
○ PROVISION FOR ACCELEROMETER MOUNTED ON BRG HOUSINGS
KEYPHASOR : STEAM TURBINE GEAR DRIVEN EQUIP.
REMARKS: ______

LUBRICATION AND CONTROL OIL SYSTEM (15.4)

REFRENCE SPECIFICATIONS: ______
FURNISHED BY ○ TURBINE MFR ☐ OTHERS
○ SEPARATE FOR TURBINE ONLY
☐ COMMON W/ DRIVEN EQUIPMENT & INCL (15.4.3)(15.4.4):

TURBINE MANUFACTURER TO SUPPLY:
○ CONTROL OIL ACCUMULATOR
○ STAINLESS STEEL OIL SUPPLY HEADING PIPING
○ OIL DRAIN HEADER PIPING
○ STAINLESS STEEL ○ CARBON STEEL
○ SIGHT FLOW INDICATORS
CONTROL OIL FILTERS ○ SINGLE ○ DUAL

OIL REQUIREMENTS:	CTRL OIL	LUBE OIL
☐ NOMINAL FLOW, m³/h		
☐ TRANSIENT FLOW, m³/h		
☐ PRESSURE, kPa		
☐ TEMPERATURE, °C		
☐ TOT. HEAT REJ, MW		
☐ OIL TYPE, Hydrocarbon/Synthetic		
☐ VISCOSITY, SSU @ 37.8°C		
☐ FILTRATION, µm		
☐ ______		
☐ ______		
☐ ______		

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1 ACCESSORIES

2 **COUPLINGS AND GUARDS (15.1.1)(15.1.2)**

3 NOTE: SEE ROTATING ELEMENTS-SHAFT ENDS
4 ○ SEE ATTACHED API 671 DATASHEET
5 COUPLING FURNISHED BY ______
6 ☐ MANUFACTURER ______ TYPE ______ MODEL ______
7 COUPLING GUARD FURNISHED BY ______
8 TYPE ○ FULLY ENCLOSED ○ SEMI OPEN ○ OTHER ______
9 COUPLING DETAILS
10 ☐ MAXIMUM OUTER DIAMETER ______ mm | ☐ VENDOR MOUNT HALF COUPLING (15.1.8)
11 ☐ HUB MASS ______ kg | ○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (15.1.6)(15.1.7)
12 ☐ SPACER LENGTH ______ mm | LUBRICATION REQUIREMENTS
13 ☐ SPACER MASS ______ kg | ○ GREASE ○ CONT. OIL LUBE ○ NONE
14 | ☐ QUANTITY PER HUB ______ kg OR m^3/h

15 **MOUNTING PLATES (15.2)**

16 BASEPLATES FURNISHED BY: ______ ______ | SOLEPLATES FURNISHED BY: ______
17 ○ UNDER TURBINE ONLY ○ OTHER(15.2.2.1) ______ | THICKNESS ______ mm
18 ○ OPEN ○ NON-SKID DECKING (15.2.2.4) ○ DRIP RIM | ○ SUBPLATES REQUIRED (15.2.3.3)
19 ○ LEVELING PADS (15.2.2.8) ○ SUITABLE FOR OPTICAL ALIGN | ○ HOLD-DOWN BOLTS FURNISHED BY ______
20 ○ SINGLE SECTION ○ MULTI-SECTION | ○ EPOXY PRIMER VENDOR (15.2.12.1.17)
21 ○ COLUMN MOUNTING (15.2.2.6) ○ SUBPLATES REQ'D (15.2.2.15) | ______
22 ○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ______ | ○ ANCHOR BOLTS FURNISHED BY (15.2.3.2): ______

23 **GEAR UNIT**

24 FURNISHED BY: ______ ○ REFERENCE API 613 ○ OTHER ______
25 SEE DATASHEETS ______ ______

26 **CONTROL AND INSTRUMENTATION (12.0)**

27 INSTRUMENTS AND CONTROL PANELS SHALL BE | ○ API 614, PAGES ______
28 IN ACCORDANCE WITH THE FOLLOWING | ○ API 670, PAGES ______
29 ATTACHED DATASHEETS: | ○ PURCHASER'S DATASHEETS ______
30 ______

31 **PROTECTIVE DEVICES**

		EXHAUST RELIEF VALVE (7.13)(15.3.1)(15.3.2)	EXTRACT./INDUCT. RELIEF VALVE (7.13)(15.4.1)(15.4.2)	VACUUM BREAKER (12.3.18)	NON-RETURN VALVE(S) (12.3.19)	THERMAL RELIEF VALVE(S) (15.3.1)
35	MOUNTING LOCATION				X	
36	SET RELIEF PRESSURE, kPa			X		
37	CAPACITY, kg/h STEAM			X		
38	VALVE MANUFACTURER					
39	VALVE TYPE					
40	VALVE SIZE/RATING					
41	FLANGE FACING (FF, RF)					
42	FURNISHED BY					
43	QUANTITY					
44						

45 **REMARKS:** ______
46 ______
47 ______
48 ______
49 ______
50 ______

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○ TRIP ○ TRIP & THROTTLE VALVES (12.3.4) ○ DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (12.3.4.2)

LOCATION: ○ MAIN INLET ○ INDUCTION
PROVIDED BY: ○ VENDOR ○ PURCHASER
☐ MANUFACTURER ______ MODEL ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______

CONSTRUCTION FEATURES:	INLET	INDUCT.
RESET: ○ MANUAL ○ HYDRAULIC		
TRIP: ○ LOCAL (MANUAL) ○ REMOTE		
EXERCISER: ○ LOCAL (MANUAL) ○ REMOTE		
○ FULLY OIL OPERATED		

☐ STRAINER: OPENING SIZE ______ (mm/MESH)
MATERIAL ______
○ TEMPORARY START-UP STRAINER ______ (MESH)
MATERIAL ______
☐ STEM MATERIAL ______ HARDNESS ______ HRC
☐ SEAT MATERIAL ______ HARDNESS ______ HRC
☐ PACKING MATERIAL ______ LEAK-OFF ______ kg/h
☐ SPRING SUPPORT OF VALVE REQUIRED
○ BY VENDOR ○ BY PURCHASER

GOVERNOR-CONTROLLED VALVE(S):

LOCATION	MAIN INLET	INDUCTION	INDUCTION EXTRACTION	INDUCTION EXTRACTION	NOTES
TRIP POSTION (OPEN/CLOSED)					
NUMBER OF VALVES					
CONNECTION SIZE					
RATING					
FACING (RF, RTJ, OTHER)					
ACTION (CAM, BAR, OTHER)					
STEM MATERIAL					
STEM MATERIAL HARDNESS, HRC					
SEAT MATERIAL					
SEAT MATERIAL HARDNESS, HRC					
PACKING MATERIAL					
PACKING LEAKOFF, kg/h					

TURNING GEAR (15.8)

○ TURNING GEAR REQUIRED (15.8.1)
○ FURNISHED BY ______
○ TYPE (15.8.5) ______ SPEED ______ r/min
○ ENGAGEMENT (15.8.2)(15.8.3)(15.8.4): ○ AUTO ○ MANUAL
○ MANUFACTURER ______ MODEL ______
○ MOUNTED BY ______
○ DRIVER: REFERENCE SPECIFICATION ______
DRIVEN BY: ○ ELECTRIC MOTOR ○ STEAM TURBINE
(15.8.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______
○ OPERATOR STATION (15.8.7) ○ LOCAL ○ REMOTE

MISCELLANEOUS

○ START-UP ASSISTANCE ______ DAYS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING AND FOUNDATION DRAWINGS
○ VENDOR WITNESS INITIAL ALIGNMENT
☐ "Y" TYPE STRAINER
☐ WATER WASHING CONNECTIONS
○ STATIC CONDUCTING BRUSHES
○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (12.3.1.8)
○ ______
○ ______

INSULATION & JACKETING (15.6)

○ BLANKET ○ OTHER ______
○ JACKETING
○ CARBON STEEL ○ STAINLESS STEEL
○ EXTENT ______

SPECIAL TOOLS (15.9)

○ COUPLING RING AND PLUG GAUGE
○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
○ OTHER ______
☐ SPREADER BEAM(S)
○ ON LOAN
○ PURCHASE

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GOVERNOR (12.2)	
TYPE ○ DIGITAL PROCESSOR BASED	○ MANUFACTURER ____ MODEL ____
○ OTHER ____	○ SUPPLIED BY ____
○ SIMPLEX ○ DUPLEX ○ TMR	
STEAM TURBINE TYPE	
○ SINGLE VALVE SINGLE STAGE	○ DOUBLE AUTOMATIC EXTRACTION
○ SINGLE VALVE MULTISTAGE	○ SINGLE AUTOMATIC EXTRACTION / INDUCTION
○ MUTIVALVE MULTISTAGE	○ DOUBLE AUTOMATIC EXTRACTION / INDUCTION
○ SINGLE AUTO EXTRACTION	○ OTHER ____
DRIVEN EQUIPMENT TYPE	
○ CENTRIFUGAL COMPRESSOR	○ SYCHRONOUS GENERATOR
○ AXIAL COMPRESSOR	○ INDUCTION GENERATOR
○ CENTRIFUGAL PUMP	○ OTHER ____
SERVICE REQUIREMENTS	
MECHANICAL DRIVE	GENERATOR DRIVE
○ SPEED CONTROL BY:	○ DROOP CONTROL
PROCESS VARIABLE ○ PRESSURE ○ FLOW	○ FREQUENCY CONTROL
EXTRACTION ○ PRESSURE ○ FLOW	○ LOAD CONTROL
INDUCTION ○ PRESSURE ○ FLOW	○ KW CONTROL
TURBINE INLET ○ PRESSURE ○ FLOW	○ KW IMPORT / EXPORT CONTROL
TURBINE EXHAUST ○ PRESSURE ○ FLOW	○ LOAD SHEDDING
OTHER ____	○ AUTOMATIC SYNCHRONIZATION
____	○ AUTOMATIC VOLTAGE REGULATION
____	○ TURBINE INLET PRESSURE LIMITING
	○ INLET PRESSURE LIMITER
INPUT/OUTPUT REQUIREMENTS	
DISCRETE INPUTS	DISCRETE OUTPUTS
○ START OR RESET	○ COMMON SHUTDOWN
○ NORMAL STOP	○ COMMON ALARM
○ EMERGENCY TRIP	○ OVERSPEED TRIP ____ r/min
○ RAISE SPEED	○ REMOTE SPEED SET POINT ENABLED
○ LOWER SPEED	○ PRESSURE CONTROL ENABLED
○ ENABLE/DISABLE REMOTE SPEED SET POINT	○ FLOW CONTROL ENABLED
○ RAMP TO MINIMUM CONTINUOUS	○ EXTRACTION CONTROL ENABLED
○ OVERSPEED TEST ENABLE	○ INDUCTION CONTROL ENABLED
○ ENABLE PRESSURE CONTROL	○ SPEED PICKUP ALARM
○ ENABLE EXTRACTION CONTROL	○ OTHER ____
○ REMOTE ALARM CLEAR/ACKNOWLEDGE	
○ ENABLE AUTO SYNCHRONIZE	
○ CASCADE RAISE/LOWER	ANALOG OUTPUTS (4 mA to 20 mA)
○ OTHER ____	○ SPEED
ANALOG INPUTS (4 mA to 20 mA)	○ SPEED SET POINT
○ REMOTE SET POINT	○ REMOTE SPEED SET POINT
○ PROCESS PRESSURE	○ EXTRACTION PRESSURE
○ EXTRACTION ○ PRESSURE ○ FLOW	○ EXTRACTION PRESSURE SET POINT
○ kW IND. LOAD ○ PRESSURE ○ FLOW	○ ACTUATOR POSITION
○ kW IMPORT / EXPORT	○ PROCESS PRESSURE
○ OTHER ____	○ kW
____	○ kW IMPORT/EXPORT
____	

	SPECIAL-PURPOSE STEAM TURBINE DATASHEET SI UNITS	JOB NO. ____ ITEM NO. ____ REVISION NO. ____ DATE ____ PAGE 8 OF 10 BY ____
1	**GOVERNOR INSTALLATION REQUIREMENTS**	
2	LOCATION ○ LOCAL (AT TURBINE)	MOUNTING ○ FLUSH MOUNT IN PANEL ○ SURFACE MOUNT
3	○ REMOTE (CONTROL ROOM)	○ VERTICAL RACK
4	○ OTHER ____	POWER SOURCE SINGLE DUAL
5	○ AREA CLASSIFICATION:	120 V (a.c.) ○ ○
6	CLASS ___ GROUP ___ DIVISION ____	220 V (a.c.) ○ ○
7	ZONE ___ GROUP ___ TEMP. RATING: ____	125 V (d.c.) ○ ○
8	ENCLOSURE ○ IP65	24 V (d.c.) ○ ○
9	○ NEMA 4	____ ○ ○
10	○ NEMA 4X	____ ○ ○
11	○ OTHER ____	
12	**LOCAL GOVERNOR CONTROL PANEL** ○ REQUIRED	○ NOT REQUIRED
13	LOCATION ○ LOCAL (AT TURBINE)	ENCLOSURE ○ IP65
14	○ REMOTE CONTROL ROOM	○ NEMA 4 ○ NEMA 4X
15	○ OTHER ____	○ OTHER ____ ___
16		○ AREA CLASSIFICATION: ____
17	OUTPUTS FROM PANEL TO GOVERNOR	CLASS ___ GROUP ___ DIVISION ____
18	○ START	ZONE ___ GROUP ___ TEMP. RATING: ____
19	○ TRIP	INPUTS TO PANEL FROM GOVERNOR
20	○ RAISE	○ COMMON ALARM TRIP
21	○ LOWER	○ TRIP LAMP
22	○ OVERSPEED TEST	○ REMOTE SET POINT ENABLED LAMP
23	○ RAMP TO MINIMUM CONTINUOUS	○ SPEED SET POINT METER
24	○ REMOTE SET POINT ENABLE/DISABLE	○ SPEED
25	○ RESET	○ OTHER ____
26	○ OTHER ____	____
27	**MISCELLANEOUS GOVERNOR DETAILS**	
28	GOVERNOR ACTION ON LOSS OF REMOTE SIGNAL:	○ LOCKS ON LAST VALUE
29		○ GOES TO MINIMUM CONTINUOUS
30		○ GOES TO MAXIMUM CONTINUOUS
31		
32	EXTERNAL INTERFACE DEVICE TYPE: ○ PRINTER	FORMAT: ○ GRAPHIC DISPLAY
33	○ CRT	○ TABULAR DATA
34	○ MODEM	○ TRENDING (REAL TIME)
35		○ HISTORICAL ARCHIVING
36	○ DISTRIBUTIVE CONTROL SYSTEM MANUFACTURER ____	○ MODEL ____
37	DATA TRANSMISSION ○ DATA LINK	○ PROTOCOL ____
38	○ DISCRETE I/O	
39	○ NETWORK TYPE ____	
40		
41	GOVERNOR SPEED PICKUP SENSORS(12.2.8):	
42	MANUFACTURER ____ MODEL ____	INSTALLATION: ○ DUAL ○ TRIPLE ○ INSTALLED SPARE
43	○ NUMBER OF TEETH IN SPEED SENSING SURFACE ____	
44		
45	ACTUATOR(S): ○ SUPPLIED BY ____	○ MANUFACTURER ____ ○ MODEL ____
45	ACTUATOR TYPE ○ HYDRAULIC ○ PNEUMATIC	○ SINGLE COIL ○ MULTICOIL ○ OTHER ____
46		
47	**TURBINE MOUNTED ACCESSORIES**	
48	TACHOMETER ○ MANUFACTURER ____	○ MODEL ____ ○ NUMBER REQUIRED. ____
49	○ LOCATION(S) ____	
50		
51		

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1 **OVERSPEED SHUTDOWN SYSTEM (12.3)**
2 ○ FURNISHED BY ______ | ○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______
3 ○ MANUFACTURER ______ ○ MODEL ______ | ○ SOLENOIDS SHALL: ○ DE-ENERGIZE TO TRIP
4 ☐ ELECTRONIC, SET POINT ______ r/min | ○ ENERGIZE TO TRIP
5 OVERSPEED SHUTDOWN REQUIREMENTS | ○ CONTACTS SHALL BE: ○ NORMALLY OPEN
6 ○ 2 OUT OF 3 VOTING LOGIC (12.3.2.1) | ○ NORMALLY CLOSED
7 ○ OTHER ______ | ○ VOLTAGE LEVEL: ______
8 ______ | ______
9 ______

10 **GLAND SEALING AND VACUUM SYSTEM (15.6)**
11 SYSTEM PER: ○ ANNEX G.1 ○ ANNEX G.2 | ○ VACUUM SYSTEM FURNISHED BY ______
12 ○ OTHER ______ | ○ SHIP LOOSE ○ SKID MOUNTED
13 ○ AVAIL. HEADER PRESSURE ______ kPa TEMPERATURE ______ °C | ○ OTHER ______
14 ○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ kPa | ○ GLAND CONDENSOR, SEE SPECIFICATION ______
15 ○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE ______ °C | ○ STEAM EJECTOR ☐ STEAM PRESS. ______ kPa
16 ☐ SEAL. STM. PRESS. ______ kPa ☐ FLOW ______ kg/h | ☐ STEAM FLOW ______ kg/h
17 ☐ SEALING STEAM RELIEF VALVE SET PRESSURE ______ kPa | ○ VACUUM PUMP (15.6.2), SEE SPECIFICATION ______
18 ○ FURNISHED BY ______ | ○ CONDENSATE RECEIVER
19 ☐ FLOW ADJUSTING VALVES, TYPE ______ | ○ LOOP SEAL HEIGHT ______ m
20 ○ FURNISHED BY ______ | ______

21 **INSPECTION AND TESTING (16.2) (16.3)**

22 **GENERAL**
23 ○ SHOP INSPECTION (16.1.4)
24 EXTENT: ______
25 ○ REFERENCE INSPECTION CHECKLIST "I"
26
27 **INSPECTION AND MATERIAL TESTING**
28 ○ FINAL ASSEMBLY RECORDS REQUIRED [16.2.1.1f)]
29 SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS

	COMPONENT	MAG PART	DYE PEN	R.T.	U.T.	OBSVD	WIT
30	COMPONENT	MAG PART	DYE PEN	R.T.	U.T.	OBSVD	WIT
31	TRIP & T & T						
32	VALVE	○	○	○	○	○	○
33	STM CHEST	○	○	○	○	○	○
34	CASING	○	○	○	○	○	○
35	PIPING	○	○	○	○	○	○
36	ROTOR	○	○	○	○	○	○
37						○	○

	ITEM	OBSVD	WIT
38	○ HEAT STABILITY (16.2.2.7)	○	○
39	○ CLEANLINESS (16.2.3.2)	○	○
40	○ HARDNESS (16.2.3.4)	○	○
41	○ HYDRO TESTS (16.3.2)	○	○
42	○ BLADE SHAKER (STATIC)	○	○
43	ROTOR BALANCE ○ STANDARD (9.7.1)(9.7.2)	○	○
44	○ HIGH SPEED (9.7.5)	○	○
45	○ LOW SPEED PRIOR TO HIGH SPEED (9.7.4)	○	○
46	○ LOW SPEED RESIDUAL UNBALANCE CHECK (9.7.3)	○	○
47	○ FINAL SURFACE INSPECTION (16.4.3)	○	○
48	○ CRATING INSPECTION (16.4.1)	○	○
49	○ SPARE ROTOR FIT	○	○
50	○ CASING JOINT LEAK TEST (16.3.2.3)	○	○
51	○ ______	○	○

MECHANICAL RUNNING TEST (16.3.3)

ITEM	OBSVD	WIT
○ CONTRACT ROTOR	○	○
○ SPARE ROTOR	○	○
○ TEST W/JOB COUPLING	○	○
○ TEST TAPE RECORD REQUIRED	○	○
○ TEST TAPE GIVEN TO PURCH.	○	○
○ TEST W/JOB LUBE OIL CONSOLE	○	○
______	○	○

OPTIONAL TESTS (16.3.4)

ITEM	OBSVD	WIT
○ PERFORMANCE (16.3.4.2)	○	○
○ COMPLETE UNIT (16.3.4.3)	○	○
○ TORSIONAL MEASMT'S (9.5.1)	○	○
AUXILIARY EQUIPMENT (16.3.4.4)		
○ TRIP/TRIP & THROTTLE VALVE	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ ______	○	○
○ CASING INTERNAL INSP (16.3.4.5)	○	○
○ COUPLING TO SHAFT FIT (API 671)	○	○
○ TURNING GEAR	○	○
○ OVERSPEED SHUTDOWN SYSTEM	○	○
○ GOVERNOR RESPONSE (16.3.4.10)	○	○
○ SOUND (16.3.4.11)	○	○
○ SPARE PARTS TESTS (16.3.4.7)	○	○
○ ______	○	○
○ ______	○	○

SPECIAL-PURPOSE STEAM TURBINE DATASHEET SI UNITS	JOB NO. ____ ITEM NO. ____ REVISION NO. ____ DATE ____ PAGE 10 OF 10 BY ____

MISCELLANEOUS

PAINTING	**WEIGHTS:**
○ MANUFACTURER'S STANDARD	☐ TURBINE ____ kg
○ OTHER ____	☐ ROTOR ____ kg
○ ____	☐ TURBINE UPPER HALF CASING ____ kg
UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI	☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ____ kg
SHIPMENT (16.4.1)[16.4.3 j)]	☐ TRIP / TRIP & THROTTLE VALVE ____ kg
○ DOMESTIC ○ EXPORT	☐ MISCELLANEOUS ____ kg
○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS	☐ TOTAL SHIPPING MASS ____ kg
○ WATERPROOF BOXING REQUIRED	
○ SPARE ROTOR ASSEMBLY PACKAGED FOR:	
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE	
SPACE REQUIREMENTS:	**VENDOR DRAWING & DATA REQUIREMENTS (17)**
☐ COMPLETE UNIT: L ____ mm W ____ mm H ____ mm	○ ANNEX J
☐ CONTROL PANEL: L ____ mm W ____ mm H ____ mm	○ OTHER ____
☐ OTHER: L ____ mm W ____ mm H ____ mm	
☐ OTHER: L ____ mm W ____ mm H ____ mm	____

REMARKS AND ADDITIONAL REQUIREMENTS:

	JOB NO. ______ ITEM NO. ______
	PURCHASE ORDER NO. ______
SPECIAL-PURPOSE STEAM TURBINE DATASHEET U.S. CUSTOMARY UNITS	SPECIFICATION NO. ______
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APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ☐ AS-BUILT

FOR ______ UNIT ______

SITE ______ SERIAL NUMBER ______

SERVICE ______ NUMBER REQUIRED ______

MANUFACTURER ______ MODEL ______ DRIVEN EQUIPMENT ITEM NO. ______

DRIVEN EQUIPMENT TYPE: ○ COMPRESSOR ○ GENERATOR ○ OTHER ______

NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ☐ PURCHASER OR MANUFACTURER

PERFORMANCE

OPERATING POINTS	SHAFT		INLET			INDUCTION/EXTRACTION			EXHAUST		
☐ AS APPLICABLE	POWER hp	SPEED r/min	FLOW lb/h	PRESS psig	TEMP °F (TT)	FLOW lb/h	PRESS psig	TEMP °F (TT)	PRESS psig/in. HgA	TEMP °F (TT)	ENTHALPY Btu/lb
RATED											
NORMAL (3.35) (6.14)											
MINIMUM											

☐ STEAM RATE, lb/hp-h (3.56): ______ NORMAL ______ RATED ______

☐ POTENTIAL MAXIMUM POWER (3.40) ______

INDUCTION ○ CONTROLLED ○ UNCONTROLLED

EXTRACTION ○ CONTROLLED ○ UNCONTROLLED

STEAM CONDITIONS

		☐ INLET	☐ EXHAUST	☐ EXTRACTION INDUCTION	☐ EXTRACTION INDUCTION	☐ EXTRACTION INDUCTION
FLOW lb/h	MAXIMUM					
	NORMAL					
	MINIMUM					
PRESSURE psig	MAXIMUM					
	NORMAL					
	MINIMUM					
TEMPERATURE °F (TT)	MAXIMUM					
	NORMAL					
	MINIMUM					

SITE AND UTILITY DATA

LOCATION:

○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR

○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE

○ OTHER: ______

○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D

○ LOW TEMPERATURE ○ CORROSIVE AGENTS

○ ELECTRICAL AREA CLASSIFICATION:

CLASS ____ GROUP ____ DIVISION ______

ZONE ____ GROUP ____ TEMPERATURE RATING: ______

SITE DATA:

○ ELEVATION ______ ft ○ BAROM. PRESS ______ psia/HgA

○ WINTER TEMP. ______ °F SUMMER TEMP. ______ °F

○ REL. HUMIDITY ______ % DESIGN WET BULB ______ °F

○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES

○ OTHER ______

UTILITY CONDITIONS:

○ AUXILIARY STEAM:	MAX	NORM	MIN
INITIAL PRESSURE (psig)	____	____	____
INITIAL TEMPERATURE, °F (TT)	____	____	____
EXHAUST PRESS. (psig/in. HgA)	____	____	____

INSTRUMENT AIR (psig): NORM ____ MIN ____ MAX ____

INSTRUMENT AIR DEW POINT: ____ °F

○ **ELECTRIC:**

	DRIVERS	HEATING	INSTRUMENT/ ALARM/ CONTROL	SHUTDOWN
VOLTS	____	____	____	____
PHASE	____	____	____	____
HERTZ	____	____	____	____
KW AVAILABLE	____	____	____	____

○ **COOLING WATER:**

INLET TEMPERATURE: ____ °F MAXIMUM RETURN ____ °F

PRESSURE NORMAL: ____ psig DESIGN: ____ psig

MINIMUM RETURN PRESSURE: ______ psig

MAXIMUM ALLOWABLE PRESSURE DROP: ______ psi

WATER SOURCE ______

VELOCITY, FPS: MIN ______ MAX ______

FOULING FACTOR: ______ h-ft²/Btu

○ **UTILITY CONSUMPTION:**

COOLING WATER: ______ GPM INST. AIR ______ SCFM

AUX. STM: NORMAL ______ lb/h MAXIMUM ______ lb/h

AUX. DRIVERS: ELECTRIC ______ hp STEAM ______ hp

HEATER(S): ______ kW OTHER: ______

REMARKS: ______

SPECIAL-PURPOSE STEAM TURBINE DATASHEET U.S. CUSTOMARY UNITS

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APPLICABLE SPECIFICATIONS:

API 612, SPECIAL-PURPOSE STEAM TURBINES
○ OTHER ____
○ VENDOR HAVING UNIT RESPONSIBILITY (3.59): ____
○ GOVERNING SPECIFICATION, IF DIFFERENT: ____

NOISE SPECIFICATIONS:

○ APPLICABLE TO MACHINE:
SEE SPECIFICATION: ____
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION: ____
ACOUSTICAL TREATMENT ○ YES ○ NO
TYPE ____

CONSTRUCTION FEATURES

TURBINE TYPE ○ BACK-PRESSURE ○ CONDENSING ○ INDUCTION ○ EXTRACTION ○ OTHER:

☐ SPEEDS:
MAXIMUM CONTINUOUS ____ r/min TRIP ____ r/min
MAXIMUM ALLOWABLE ____ r/min
☐ LATERAL CRITICAL SPEEDS (DAMPED) (9.2)
FIRST CRITICAL ____ r/min ____ MODE
SECOND CRITICAL ____ r/min ____ MODE
THIRD CRITICAL ____ r/min ____ MODE
FOURTH CRITICAL ____ r/min ____ MODE
☐ VIBRATION ____ mil (PEAK TO PEAK)

☐ TORSIONAL CRITICAL SPEEDS (9.6):
FIRST CRITICAL ____ r/min
SECOND CRITICAL ____ r/min
THIRD CRITICAL ____ r/min
FOURTH CRITICAL ____ r/min
○ LATERAL ANALYSIS REPORT REQUIRED
○ INDIVIDUAL BODY ○ TRAIN
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED
○ TRAIN TORSIONAL PERFORMED BY

☐ **CASINGS, NOZZLES & DIAPHRAGMS**

☐ MAWP (3.23) (7.13)
INLET SECTION ____ psig EXH. SECTION ____ psig
INDUCTION / EXTRACT. SECTION ____ psig
OTHER ____ psig
☐ MAX OPERATING TEMP. (3.22)(3.27)
INLET SECTION ____ °F EXHAUST SECTION ____ °F
INDUCTION / EXTRACTION SECTION ____ °F
○ MINIMUM DESIGN METAL TEMPERATURE(11.1.15) ____ °F
○ RELIEF VALVE SETTING INLET ____ psig ____ psig
EXTRACTION ____ psig OTHER ____ psig

☐ HYDRO TEST PRESSURE (16.3.2.2)
HP CASING ____ psig MID CASING ____ psig
EXHAUST CASING ____ psig OTHER ____ psig
○ WELDED NOZZLE RING (7.3.1) NOZZLE RING ____ %ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST ☐ WELDED
(7.3.2) ☐ OTHER ____
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	☐ SIZE	☐ FACING	○ POSTION	○ FLANGED OR STUDDED (7.2.1) (7.2.3)	○ MATING FLG. & GASKET BY VENDOR [7.2.8)]	☐ MAXIMUM STEAM FLOW lb/h	☐ MINIMUM STEAM FLOW lb/h
INLET							
EXHAUST							
EXTRACTION							
INDUCTION							

AUX. SCRWD. PIPE CONN.: ○ TAPERED ○ STRAIGHT ○ MAIN CASING JOINT STUDS / NUTS DESIGNED FOR HYD. TENSIONING [7.1.15 f)]

☐ **ALLOWABLE FORCES & MOMENTS**

	INLET		EXHAUST		EXTRACT. / INDUCT.	
	FORCE	MOMENT	FORCE	MOMENT	FORCE	MOMENT
	lb	ft-lb	lb	ft-lb	lb	ft-lb
PARALLEL TO SHAFT						
VERTICAL						
HORZ. 90°						

ROTATION :(VIEWED FROM INLET END)

○ CW ○ CCW

SPECIAL-PURPOSE STEAM TURBINE DATASHEET U.S. CUSTOMARY UNITS

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MATERIALS-CASINGS & APPURTENANCES:

☐ HIGH PRESSURE CASING ______
☐ MID PRESSURE CASING ______
☐ EXHAUST CASING ______
☐ STEAM CHEST ______
☐ NOZZLE RING ______
○ STEAM CONTAMINANTS (11.1.6) ______
○ STEAM PATH COMPONENTS < HRC 22 (11.1.9)

☐ DIAPHRAGM/BLADE CARRIERS ______
☐ DIAPHRAGM NOZZLES ______
☐ OTHER ______

ROTATING ELEMENTS (8)

SHAFT TYPE:
☐ INTEGRAL WHEELS ☐ BUILT-UP (8.1.2) ☐ COMBINATION
☐ DOUBLE EXTENDED
☐ NUMBER OF STAGES ______ BEARING SPAN ______ in.
☐ SHAFT MATERIAL ______
BLADES(BUCKETS): ☐ MAXIMUM TIP SPEED ______ ft/min
☐ FINAL STAGE BLADE LENGTH ______ in. MAX. ______ in.
REMARKS: ______

☐ SHAFT ENDS: DIAMETER @ COUPLING ______ in.
○ STRAIGHT ○ TAPER ______ in./ft
○ KEYED ○ SINGLE ○ DOUBLE
○ HYDRAULIC FIT ○ INTEGRAL FLANGE
○ FIELD BALANCING PROVISIONS REQUIRED (8.1.4)
☐ DESCRIPTION OF FIELD BALANCING PROVISIONS: ______
REMARKS: ______

	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE
☐ WHEEL MATERIAL							
☐ BLADE MATERIAL							
☐ BLADE ROOT TYPE							
☐ CLOSURE PIECE TYPE							
☐ TIE WIRE MATERIAL							
☐ SHROUD MATERIAL							
☐ SHROUD ATTACH.							
☐ PITCH DIAMETER, in.							
☐ BLADE HEIGHT, in.							
☐ BLADE TYPE							
☐ ______							
☐ ______							

SHAFT SEALS (10.6)

	INLET	EXHAUST
☐ MAX. SEAL PRESSURE, psig		
☐ STEAM LEAKAGE, lb/h		
☐ AIR LEAKAGE, SCFM		
☐ SHAFT DIAMETER @ SEAL, in.		
☐ STATIONARY LABY. TYPE		
☐ ROTATING LABY. TYPE		
☐ MATERIAL		
☐		
☐		
☐ ______		

TYPE: ○ LABYRINTH (10.6.1) ○ OTHER ______
MATERIAL: ______

INTERSTAGE SEALS (10.6.2):
TYPE: ○ LABYRINTH
○ OTHER ______
MATERIAL: ______

REMARKS: ______

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BEARINGS AND BEARING HOUSINGS

RADIAL (10.1)(10.2)

	INLET	EXHAUST
TYPE		
MANUFACTURER		
LENGTH (in.)		
SHAFT DIAMETER (in.)		
UNIT LOAD (ACT/ALLOW)(psi)		
BASE MATERIAL		
BABBIT THICKNESS (in.)		
NUMBER OF PADS		
LOAD: BETWEEN/ON PAD		
PIVOT: CENTER/OFFSET %		
______		
______		

THRUST (10.1)(10.3)

	ACTIVE	INACTIVE
TYPE		
MANUFACTURER		
UNIT LOADING MAX. (psi)		
UNIT LOAD ULTIMATE (psi)		
NUMBER OF PADS		
AREA (in.²)		
PIVOT: CENTER / OFFSET, %		
PAD BASE MATERIAL		

LUBRICATION: ○ FLOODED ○ DIRECTED

THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE

BEARING TEMPERATURE DEVICES:

○ THERMOCOUPLES ○ TYPE ______

○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______

○ RESISTANCE TEMPERATURE DETECTORS

○ RESISTANCE MATERIAL ______ ☐ ______ ohm

○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______ MFR

○ LOCATION-JOURNAL BEARING

TOTAL ______ LOCATION ______

SCALE RANGE ______ ALARM SET @ ______ °F

SHUTDOWN SET @ ______ °F DELAY ______ s

○ LOCATION-THRUST BEARING

ACTIVE SIDE

TOTAL ______ LOCATION ______

INACTIVE SIDE

TOTAL ______ LOCATION ______

SCALE RANGE ______ ALARM SET @ ______ °F

SHUTDOWN SET @ ______ °F DELAY ______ s

○ MONITOR SUPPLIED BY: ______

○ LOCATION ______ ENCLOSURE ______

○ MFR. ______ ☐ MODEL ______

______

______

______

VIBRATION DETECTORS:

○ TYPE ______ ☐ MODEL ______

○ MANUFACTURER ______

○ NUMBER AT EACH SHAFT BRG ______ TOTAL NUMBER ______

MONITOR SUPPLIED BY ______

○ LOCATION ______ ENCLOSURE ______

○ MFR ______ ☐ MODEL ______

☐ SCALE RANGE ______ ALARM ☐ SET @ ______ mil

○ SHUTDOWN: ☐ SET @ ______ mil ○ DELAY ______ s

AXIAL POSITION DETECTORS:

○ TYPE ______ ☐ MODEL ______

○ MFR ______ ○ NUMBER REQUIRED ______

MONITOR SUPPLIED BY ______

○ LOCATION ______ ENCLOSURE ______

○ MFR ______ ☐ MODEL ______

☐ SCALE RANGE ______ ALARM ☐ SET @ ______ mil

○ SHUTDOWN ☐ SET @ ______ mil ○ DELAY ______ s

○ PROVISION FOR ACCELEROMETER MOUNTED ON BRG HOUSINGS

KEYPHASOR: ○ STEAM TURBINE ○ GEAR ○ DRIVEN EQUIP.

REMARKS: ______

______

______

______

______

LUBRICATION AND CONTROL OIL SYSTEM (15.4)

REFRENCE SPECIFICATIONS: ______

FURNISHED BY ○ TURBINE MFR ○ OTHERS

○ SEPARATE FOR TURBINE ONLY

○ COMMON W/ DRIVEN EQUIPMENT & INCL (15.4.3) (15.4.4):

______

TURBINE MANUFACTURER TO SUPPLY:

○ CONTROL OIL ACCUMULATOR

○ STAINLESS STEEL OIL SUPPLY HEADING PIPING

○ OIL DRAIN HEADER PIPING

○ STAINLESS STEEL ○ CARBON STEEL

○ SIGHT FLOW INDICATORS

CONTROL OIL FILTERS ○ SINGLE ○ DUAL

OIL REQUIREMENTS:	CTRL OIL	LUBE OIL
NOMINAL FLOW, U.S. gal/min		
TRANSIENT FLOW, U.S. gal/min		
PRESSURE, psig		
TEMPERATURE, °F		
TOT. HEAT REJ, Btu/h		
OIL TYPE, Hydrocarbon/Synthetic		
VISCOSITY, SSU @ 100°F		
FILTRATION, microns		
______		
______		
______		

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ACCESSORIES

COUPLINGS AND GUARDS (15.1.1)(15.1.2)

NOTE: SEE ROTATING ELEMENTS-SHAFT ENDS

○ SEE ATTACHED API 671 DATASHEET

COUPLING FURNISHED BY ____

☒ MANUFACTURER ____ TYPE ____ MODEL ____

COUPLING GUARD FURNISHED BY ____

TYPE ○ FULLY ENCLOSED ○ SEMI OPEN ○ OTHER ____

COUPLING DETAILS	
☐ MAXIMUM OUTER DIAMETER ____ in.	☒ VENDOR MOUNT HALF COUPLING (15.1.8)
☐ HUB WEIGHT ____ lb	○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (15.1.6) (15.1.7)
☐ SPACER LENGTH ____ in.	LUBRICATION REQUIREMENTS
☐ SPACER MASS ____ lb	○ GREASE ○ CONT. OIL LUBE ○ NONE
	☐ QUANTITY PER HUB ____ lb OR U.S. gal/min

MOUNTING PLATES (15.2)

BASEPLATES FURNISHED BY: ____	SOLEPLATES FURNISHED BY: ____
○ UNDER TURBINE ONLY ○ OTHER (15.2.2.1) ____	THICKNESS ____ IN.
○ OPEN ○ NON-SKID DECKING (15.2.2.4) ○ DRIP RIM	○ SUBPLATES REQUIRED (15.2.3.3)
○ LEVELING PADS (15.2.2.8) ○ SUITABLE FOR OPTICAL ALIGN	○ HOLD-DOWN BOLTS FURNISHED BY ____
○ SINGLE SECTION ○ MULTI-SECTION	○ EPOXY PRIMER VENDOR (15.2.12.1.17)
○ COLUMN MOUNTING (15.2.2.6) ○ SUBPLATES REQ'D (15.2.2.15)	____
○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ____	○ ANCHOR BOLTS FURNISHED BY (15.2.3.2): ____

GEAR UNIT

FURNISHED BY: ____ ○ REFERENCE API 613 ○ OTHER ____

○ SEE ATTACHED GEAR DATASHEETS ____ ____

CONTROL AND INSTRUMENTATION (12.0)

INSTRUMENTS AND CONTROL PANELS SHALL BE	○ API-614 APPENDIX B, PAGES ____
IN ACCORDANCE WITH THE FOLLOWING	○ API 670 APPENDIX D, PAGES ____
ATTACHED DATASHEETS:	○ PURCHASER'S DATASHEETS ____
	____

PROTECTIVE DEVICES

	EXHAUST RELIEF VALVE (7.1.3)(15.3.1)(15.4.2)	EXTRACT./INDUCT. RELIEF VALVE (7.1.3)(15.4.1)(15.3.2)	VACUUM BREAKER (12.3.1.8)	NON-RETURN VALVE(S) (12.3.1.9)	THERMAL RELIEF VALVE(S) (15.3.1)
MOUNTING LOCATION				X	
SET RELIEF PRESSURE, psig			X		
CAPACITY, lb/h STEAM			X		
VALVE MANUFACTURER					
VALVE TYPE					
VALVE SIZE/RATING					
FLANGE FACING (FF, RF)					
FURNISHED BY					
QUANTITY					

REMARKS: ____

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○ TRIP ○ TRIP & THROTTLE VALVES (12.3.4) ○ DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (12.3.4.2)

LOCATION: ○ MAIN INLET ○ INDUCTION
PROVIDED BY: ○ VENDOR ○ PURCHASER
☐ MANUFACTURER ______ MODEL ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______

CONSTRUCTION FEATURES:	INLET	INDUCT.
RESET: ○ MANUAL ○ HYDRAULIC		
TRIP: ○ LOCAL (MANUAL) ○ REMOTE		
EXERCISER: ○ LOCAL (MANUAL) ○ REMOTE		
○ FULLY OIL OPERATED		

☐ STRAINER: OPENING SIZE ______ (in./MESH)
MATERIAL ______
○ TEMPORARY START-UP STRAINER ______ (MESH)
MATERIAL ______
☐ STEM MATERIAL ______ HARDNESS ______ HRC
☐ SEAT MATERIAL ______ HARDNESS ______ HRC
☐ PACKING MATERIAL ______ LEAK-OFF ______ lb/h
☐ SPRING SUPPORT OF VALVE REQUIRED
○ BY VENDOR ○ BY PURCHASER

GOVERNOR-CONTROLLED VALVE(S):

LOCATION	MAIN INLET	INDUCTION	INDUCTION EXTRACTION	INDUCTION EXTRACTION	NOTES
TRIP POSTION (OPEN/CLOSED)					
NUMBER OF VALVES					
CONNECTION SIZE					
RATING					
FACING (RF, RTJ, OTHER)					
ACTION (CAM, BAR, OTHER)					
STEM MATERIAL					
STEM MATERIAL HARDNESS, HRC					
SEAT MATERIAL					
SEAT MATERIAL HARDNESS, HRC					
PACKING MATERIAL					
PACKING LEAK-OFF, lb/h					

TURNING GEAR (15.8)

○ TURNING GEAR REQUIRED (15.8.1)
○ FURNISHED BY ______
○ TYPE (15.8.5) ______ SPEED ______ r/min
○ ENGAGEMENT (15.8.2)(15.8.3)(15.8.4): ○ AUTO ○ MANUAL
○ MANUFACTURER ______ MODEL ______
○ MOUNTED BY ______
○ DRIVER: REFERENCE SPECIFICATION ______
DRIVEN BY: ○ ELECTRIC MOTOR ○ STEAM TURBINE
(15.8.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______
○ OPERATOR STATION (15.8.7) ○ LOCAL ○ REMOTE

MISCELLANEOUS

○ START-UP ASSISTANCE ______ DAYS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING AND FOUNDATION DRAWINGS
○ VENDOR WITNESS INITIAL ALIGNMENT
☐ "Y" TYPE STRAINER
☐ WATER WASHING CONNECTIONS
○ STATIC CONDUCTING BRUSHES
○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (12.3.1.8)
○ ______
○ ______

INSULATION & JACKETING (15.6)

○ BLANKET ○ OTHER ______
○ JACKETING
○ CARBON STEEL ○ STAINLESS STEEL
○ EXTENT ______
______
______

SPECIAL TOOLS (15.9)

○ COUPLING RING AND PLUG GAUGE
○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
○ OTHER ______
☐ SPREADER BEAM(S)
○ ON LOAN
○ PURCHASE

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GOVERNOR (12.2)	
TYPE ○ DIGITAL PROCESSOR BASED	○ MANUFACTURER ______ MODEL ______
○ OTHER ______	○ SUPPLIED BY ______
○ SIMPLEX ○ DUPLEX ○ TMR	
STEAM TURBINE TYPE	
○ SINGLE VALVE SINGLE STAGE	○ DOUBLE AUTOMATIC EXTRACTION
○ SINGLE VALVE MULTISTAGE	○ SINGLE AUTOMATIC EXTRACTION / INDUCTION
○ MUTIVALVE MULTISTAGE	○ DOUBLE AUTOMATIC EXTRACTION / INDUCTION
○ SINGLE AUTO EXTRACTION	○ OTHER ______
DRIVEN EQUIPMENT TYPE	
○ CENTRIFUGAL COMPRESSOR	○ SYCHRONOUS GENERATOR
○ AXIAL COMPRESSOR	○ INDUCTION GENERATOR
○ CENTRIFUGAL PUMP	○ OTHER ______
SERVICE REQUIREMENTS	
MECHANICAL DRIVE	GENERATOR DRIVE
○ SPEED CONTROL BY:	○ DROOP CONTROL
PROCESS VARIABLE ○ PRESSURE ○ FLOW	○ FREQUENCY CONTROL
EXTRACTION ○ PRESSURE ○ FLOW	○ LOAD CONTROL
INDUCTION ○ PRESSURE ○ FLOW	○ KW CONTROL
TURBINE INLET ○ PRESSURE ○ FLOW	○ KW IMPORT / EXPORT CONTROL
TURBINE EXHAUST ○ PRESSURE ○ FLOW	○ LOAD SHEDDING
OTHER ______	○ AUTOMATIC SYNCHRONIZATION
______	○ AUTOMATIC VOLTAGE REGULATION
______	○ TURBINE INLET PRESSURE LIMITING
	○ INLET PRESSURE LIMITER
INPUT/OUTPUT REQUIREMENTS	
DISCRETE INPUTS	DISCRETE OUTPUTS
○ START OR RESET	○ COMMON SHUTDOWN
○ NORMAL STOP	○ COMMON ALARM
○ EMERGENCY TRIP	○ OVERSPEED TRIP ______ r/min
○ RAISE SPEED	○ REMOTE SPEED SET POINT ENABLED
○ LOWER SPEED	○ PRESSURE CONTROL ENABLED
○ ENABLE/DISABLE REMOTE SPEED SET POINT	○ FLOW CONTROL ENABLED
○ RAMP TO MINIMUM CONTINUOUS	○ EXTRACTION CONTROL ENABLED
○ OVERSPEED TEST ENABLE	○ INDUCTION CONTROL ENABLED
○ ENABLE PRESSURE CONTROL	○ SPEED PICKUP ALARM
○ ENABLE EXTRACTION CONTROL	○ OTHER ______
○ REMOTE ALARM CLEAR/ACKNOWLEDGE	
○ ENABLE AUTO SYNCHRONIZE	
○ CASCADE RAISE/LOWER	ANALOG OUTPUTS (4 mA to 20 mA)
○ OTHER ______	○ SPEED
ANALOG INPUTS (4 mA to 20 mA)	○ SPEED SET POINT
○ REMOTE SET POINT	○ REMOTE SPEED SET POINT
○ PROCESS PRESSURE	○ EXTRACTION PRESSURE
○ EXTRACTION ○ PRESSURE ○ FLOW	○ EXTRACTION PRESSURE SET POINT
○ kW IND. LOAD ○ PRESSURE ○ FLOW	○ ACTUATOR POSITION
○ kW IMPORT / EXPORT	○ PROCESS PRESSURE
○ OTHER ______	○ kW
______	○ kW IMPORT/EXPORT
______	

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1 **GOVERNOR INSTALLATION REQUIREMENTS**

2	LOCATION ○ LOCAL (AT TURBINE)	MOUNTING ○ FLUSH MOUNT IN PANEL ○ SURFACE MOUNT
3	○ REMOTE (CONTROL ROOM)	○ VERTICAL RACK
4	○ OTHER	POWER SOURCE SINGLE DUAL
5	○ AREA CLASSIFICATION:	120 V (a.c.) ○ ○
6	CLASS ___ GROUP ___ DIVISION ___	220 V (a.c.) ○ ○
7	ZONE ___ GROUP ___ TEMP. RATING: ___	125 V (d.c.) ○ ○
8	ENCLOSURE ○ IP65	24 V (d.c.) ○ ○
9	○ NEMA 4	______ ○ ○
10	○ NEMA 4X	______ ○ ○
11	○ OTHER ______	

12 **LOCAL GOVERNOR CONTROL PANEL** ○ REQUIRED ○ NOT REQUIRED

13	LOCATION ○ LOCAL (AT TURBINE)	ENCLOSURE ○ IP65
14	○ REMOTE CONTROL ROOM	○ NEMA 4 ○ NEMA 4X
15	○ OTHER ______	○ OTHER ______
16		○ AREA CLASSIFICATION: ______
17	OUTPUTS FROM PANEL TO GOVERNOR	CLASS ___ GROUP ___ DIVISION ___
18	○ START	ZONE ___ GROUP ___ TEMP. RATING: ___
19	○ TRIP	INPUTS TO PANEL FROM GOVERNOR
20	○ RAISE	○ COMMON ALARM TRIP
21	○ LOWER	○ TRIP LAMP
22	○ OVERSPEED TEST	○ REMOTE SET POINT ENABLED LAMP
23	○ RAMP TO MINIMUM CONTINUOUS	○ SPEED SET POINT METER
24	○ REMOTE SET POINT ENABLE/DISABLE	○ SPEED
25	○ RESET	○ OTHER ______
26	○ OTHER ______	______

27 **MISCELLANEOUS GOVERNOR DETAILS**

28 GOVERNOR ACTION ON LOSS OF REMOTE SIGNAL: ○ LOCKS ON LAST VALUE
29 ○ GOES TO MINIMUM CONTINUOUS
30 ○ GOES TO MAXIMUM CONTINUOUS
31
32 EXTERNAL INTERFACE DEVICE TYPE: ○ PRINTER FORMAT: ○ GRAPHIC DISPLAY
33 ○ CRT ○ TABULAR DATA
34 ○ MODEM ○ TRENDING (REAL TIME)
35 ○ HISTORICAL ARCHIVING
36 ○ DISTRIBUTIVE CONTROL SYSTEM MANUFACTURER ______ ○ MODEL ______
37 DATA TRANSMISSION ○ DATA LINK ○ PROTOCOL ______
38 ○ DISCRETE I/O
39 ○ NETWORK TYPE ______
40
41 GOVERNOR SPEED PICKUP SENSORS (12.2.8):
42 MANUFACTURER ______ MODEL ______ INSTALLATION: ○ DUAL ○ TRIPLE ○ INSTALLED SPARE
43 ○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______
44
45 ACTUATOR(S): ○ SUPPLIED BY ______ ○ MANUFACTURER ______ ○ MODEL ______
45 ACTUATOR TYPE ○ HYDRAULIC ○ PNEUMATIC ○ SINGLE COIL ○ MULTICOIL ○ OTHER ______
46

47 **TURBINE MOUNTED ACCESSORIES**

47 TACHOMETER ○ MANUFACTURER ______ ○ MODEL ______ ○ NUMBER REQUIRED. ______
48 ○ LOCATION(S) ______
49
50

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OVERSPEED SHUTDOWN SYSTEM (12.3)

○ FURNISHED BY ______
○ MANUFACTURER ______ ○ MODEL ______
☐ ELECTRONIC, SET POINT ______ r/min
OVERSPEED SHUTDOWN REQUIREMENTS
○ 2 OUT OF 3 VOTING LOGIC (12.3.2.1)
○ OTHER ______

○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______
○ SOLENOIDS SHALL: ○ DE-ENERGIZE TO TRIP ○ ENERGIZE TO TRIP
○ CONTACTS SHALL BE: ○ NORMALLY OPEN ○ NORMALLY CLOSED
○ VOLTAGE LEVEL: ______

GLAND SEALING AND VACUUM SYSTEM (15.6)

SYSTEM PER: ○ ANNEX G.1 ○ ANNEX G.2 ○ OTHER ______
○ AVAIL. HEADER PRESSURE ______ psig TEMPERATURE ______ °F
○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ psig
○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE. ______ °F
☐ SEALING STEAM PRESSURE ______ psig ☐ FLOW ______ lb/h
☐ SEALING STEAM . RELIEF VALVE SET PRESSURE ______ psig
○ FURNISHED BY ______
☐ FLOW ADJUSTING VALVES, TYPE ______
○ FURNISHED BY ______

○ VACUUM SYSTEM FURNISHED BY ______
○ SHIP LOOSE ○ SKID MOUNTED
○ OTHER ______
○ GLAND CONDENSOR, SEE SPECIFICATION ______
○ STEAM EJECTOR ☐ STEAM . PRESSURE ______ psig
☐ STM . FLOW ______ lb/h
○ VACUUM PUMP (15.6.2), SEE SPEC. ______
○ CONDENSATE RECEIVER
○ LOOP SEAL HEIGHT ______ ft

INSPECTION AND TESTING (16.2) (16.3)

GENERAL

○ SHOP INSPECTION (16.1.4)
EXTENT: ______
○ REFERENCE INSPECTION CHECKLIST "I"

INSPECTION AND MATERIAL TESTING

○ FINAL ASSEMBLY RECORDS REQUIRED [16.2.1.1f)]
SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS

COMPONENT	MAG PART	DYE PEN	R.T.	U.T.	OBSVD	WIT
TRIP & T & T						
VALVE	○	○	○	○	○	○
STM CHEST	○	○	○	○	○	○
CASING	○	○	○	○	○	○
PIPING	○	○	○	○	○	○
ROTOR	○	○	○	○	○	○
					○	○

	OBSVD	WIT
○ HEAT STABILITY (16.2.2.7)	○	○
○ CLEANLINESS (16.2.3.2)	○	○
○ HARDNESS (16.2.3.4)	○	○
○ HYDRO TESTS (16.3.2)	○	○
○ BLADE SHAKER (STATIC)	○	○
ROTOR BALANCE ○ STANDARD (9.7.1)(9.7.2)	○	○
○ HIGH SPEED (9.7.5)	○	○
○ LOW SPEED PRIOR TO HIGH SPEED (9.7.4)	○	○
○ LOW SPEED RESIDUAL UNBALANCE CHECK (9.7.3)	○	○
○ FINAL SURFACE INSPECTION (16.4.3)	○	○
○ CRATING INSPECTION (16.4.1)	○	○
○ SPARE ROTOR FIT	○	○
○ CASING JOINT LEAK TEST (16.3.2.3)	○	○
○ ______	○	○

MECHANICAL RUNNING TEST (16.3.3)

	OBSVD	WIT
○ CONTRACT ROTOR	○	○
○ SPARE ROTOR	○	○
○ TEST W/JOB COUPLING	○	○
○ TEST TAPE RECORD REQUIRED	○	○
○ TEST TAPE GIVEN TO PURCH.	○	○
○ POLAR PLOTS REQUIRED	○	○
○ TEST W/JOB LUBE OIL CONSOLE	○	○

OPTIONAL TESTS (16.3.4)

	OBSVD	WIT
○ PERFORMANCE (16.3.4.2)	○	○
○ COMPLETE UNIT (16.3.4.3)	○	○
○ TORSIONAL MEASM'T'S (9.5.1)	○	○
AUXILIARY EQUIPMENT (16.3.4.4)		
○ TRIP/TRIP & THROTTLE VALVE	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ ______	○	○
○ CASING INTERNAL INSP (16.3.4.5)	○	○
○ COUPLING TO SHAFT FIT (API 671)	○	○
○ TURNING GEAR	○	○
○ OVERSPEED SHUTDOWN SYSTEM	○	○
○ GOVERNOR RESPONSE (16.3.4.10)	○	○
○ SOUND (16.3.4.11)	○	○
○ SPARE PARTS TESTS (16.3.4.7)	○	○
○ ______	○	○
○ ______	○	○

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MISCELLANEOUS

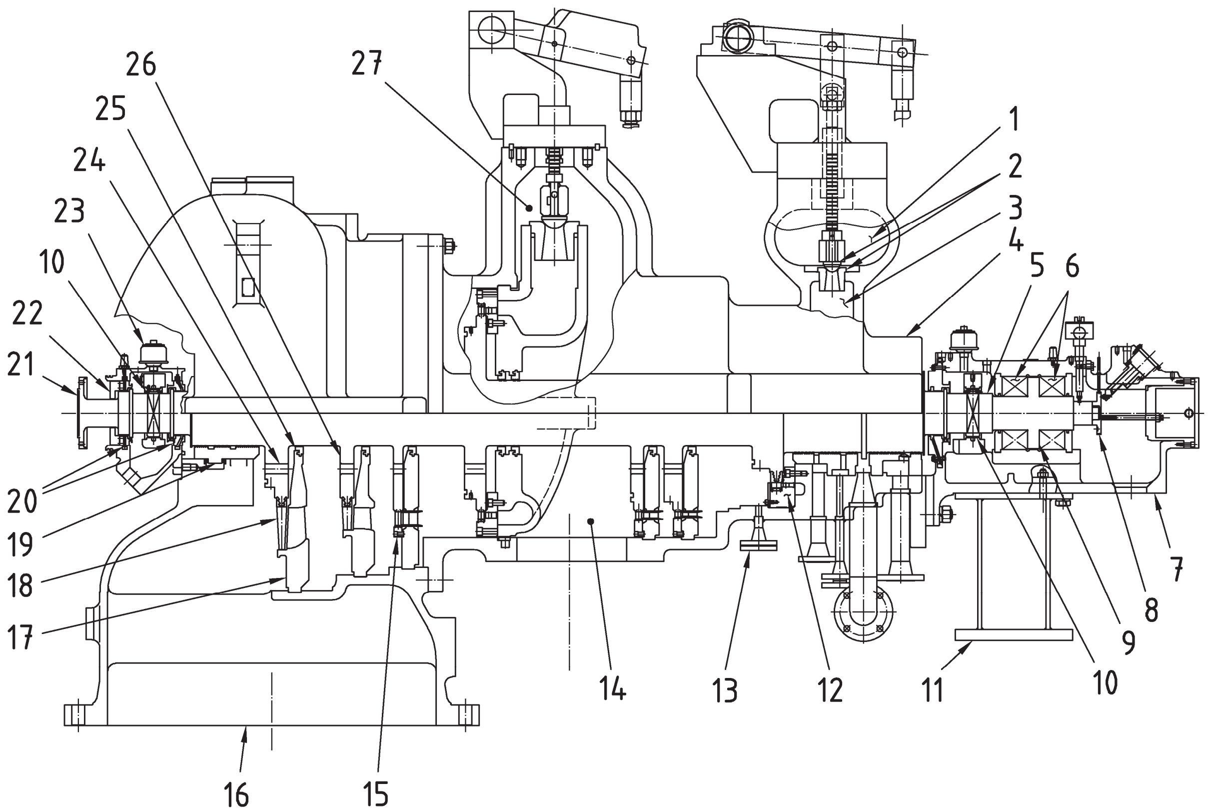
PAINTING	**WEIGHTS:**
○ MANUFACTURER'S STANDARD	☐ TURBINE ____ lb
○ OTHER ____	☐ ROTOR ____ lb
	☐ TURBINE UPPER HALF CASING ____ lb
UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI	☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ____ lb
SHIPMENT (16.4.1) [16.4.3 j)]	☐ TRIP / TRIP & THROTTLE VALVE ____ lb
○ DOMESTIC ○ EXPORT	☐ MISCELLANEOUS ____ lb
○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS	☐ TOTAL SHIPPING MASS ____ lb
○ WATERPROOF BOXING REQUIRED	
○ SPARE ROTOR ASSEMBLY PACKAGED FOR:	
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE	
SPACE REQUIREMENTS:	**VENDOR DRAWING & DATA REQUIREMENTS (17)**
☐ COMPLETE UNIT: L ____ in. W ____ in. H ____ in.	○ ANNEX J
☐ CONTROL PANEL: L ____ in. W ____ in. H ____ in.	○ OTHER ____
☐ OTHER: L ____ in. W ____ in. H ____ in.	____
☐ OTHER: L ____ in. W ____ in. H ____ in.	____

REMARKS AND ADDITIONAL REQUIREMENTS:

Annex B
(informative)

Steam Turbine Nomenclature

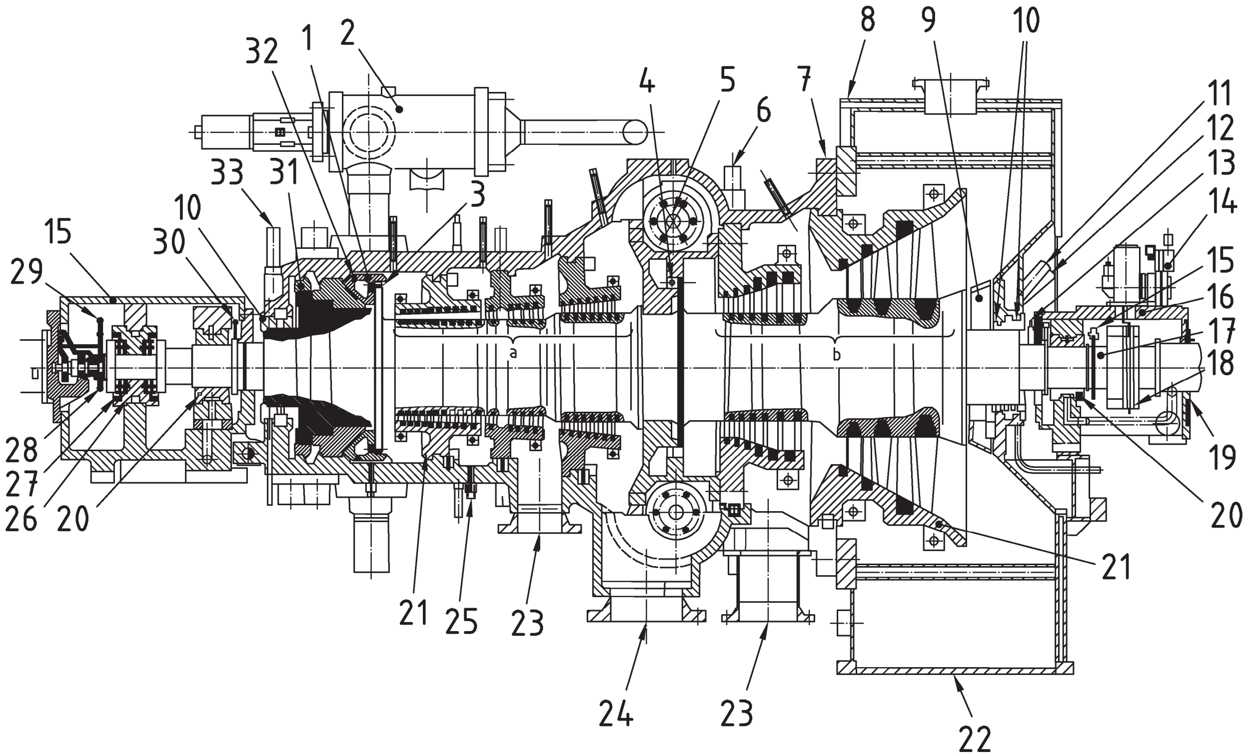
Figure B.1 and Figure B.2 are included only to clarify the nomenclature for standard machine parts and are in no way intended to show preferred design solutions or establish any design requirements whatsoever. The machine parts depicted here might not all be present in each turbine or might have a different appearance, 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 with this standard.



Key

1	steam chest	10	journal bearing	19	shaft outer seals
2	inlet valves and seats	11	support	20	bearing housing end seals
3	nozzle chamber	12	control stage nozzle ring	21	rotor
4	casing	13	casing drain	22	bearing housing deflector
5	rotor shaft sensing area	14	controlled extraction/injection nozzle	23	breather/vent
6	thrust bearings	15	tip seal	24	steam balance hole
7	bearing housing	16	exhaust connection	25	interstage seals
8	multi-toothed speed sensing surface	17	diaphragm	26	wheel (disk)
9	thrust collar	18	rotor blades	27	low-pressure section control valves

Figure B.1—Typical Impulse Steam Turbine Nomenclature



[a] High-pressure staging.

[b] Low-pressure staging.

Key

1 high-pressure nozzle element
2 inlet control valves
3 control stage impulse blading
4 low-pressure nozzles inner casing
5 low-pressure control valves
6 balancing line
7 turbine casing
8 exhaust casing
9 diffuser
10 labyrinth seals
11 waste steam nozzle
12 seal steam supply
13 rotor ground
14 turning gear
15 relative expansion pickup
16 bearing housing
17 rotor
18 gear wheel
19 bearing housing end seals
20 journal bearing
21 blade carrier
22 exhaust connection
23 bleeding/injection nozzle
24 controlled extraction/injection nozzle
25 casing drain
26 thrust bearing
27 pads
28 multi-toothed speed sensing surface
29 speed pickup
30 shaft vibration pickup
31 balance piston
32 high-pressure nozzles inner casing
33 balance line

Figure B.2—Typical Reaction Steam Turbine Nomenclature

Annex C
(normative)

Procedures for Determining Residual Unbalance

C.1 Scope

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

C.2 Terms and Definitions

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

C.2.1
residual unbalance
Amount of unbalance remaining in a rotor after balancing.

NOTE Unless otherwise specified, residual unbalance is expressed in g-mm (oz-in.).

C.3 Maximum Allowable Residual Unbalance

C.3.1 The maximum allowable residual unbalance per plane shall be calculated in accordance with 9.7.2, using Equation (13).

C.3.2 If the actual static load on each journal is not known, it shall be assumed that the total rotor mass is equally supported by the bearings.

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.

C.4 Residual Unbalance Check

C.4.1 General

C.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.

C.4.1.2 To check the residual unbalance, a known trial mass is attached to the rotor sequentially in six equally spaced radial positions (or twelve, if specified by the purchaser), 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 C.4.2.

C.4.2 Procedure

C.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].

C.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.

C.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 readout display. Compare this with the unbalance indicated without the trial mass. If a greater than expected change occurs, a smaller trial mass should be used. If little or no change is observed, a larger trial mass should be used. Little or no change generally indicates that the rotor was not balanced correcly, the balance 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.

C.4.2.4 Locate the trial mass at each of the equally spaced postions in turn, and record the amplitude of unbalance indicated by the balance machine readout display for each position. Repeat the initial position as a check. All verification shall be performed using only one sensititity range on the balance machine.

C.4.2.5 Plot the readings on the residual unbalance worksheet and calculate the amount of residual unbalance (see Figure C.1). The maximum amplitude 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 a approxiamte circle (see Figure C.2). An average of the maximum and minimum amplitude 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.

C.4.2.6 Repeat the steps in accordance with C.4.2.1 to C.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.

C.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 multi-component rotor with a faulty balancing machine.

Equipment (rotor) no.: ____________________

Purchase order no.: ____________________

Correction plane (inlet, drive end, etc.—use sketch):

Balancing speed: ____________________ r/min

n = maximum allowable rotor speed: ____________________ r/min

m = mass of journal (closest to this correction plane): ____________________ kg(lb)

U_{max} = maximum allowable residual unbalance =

6350 m/n (4 m/n)

6350 × _________ kg/ _______ r/min; (4 min × _______ 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/ _______ (______ 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	300°	
Repeat 1	0°	

Test Data—Graphic Analysis

Step 1: Plot data on the polar chart (Figure C.1 continued). Scale the chart so the largest and smallest amplitudes fit 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

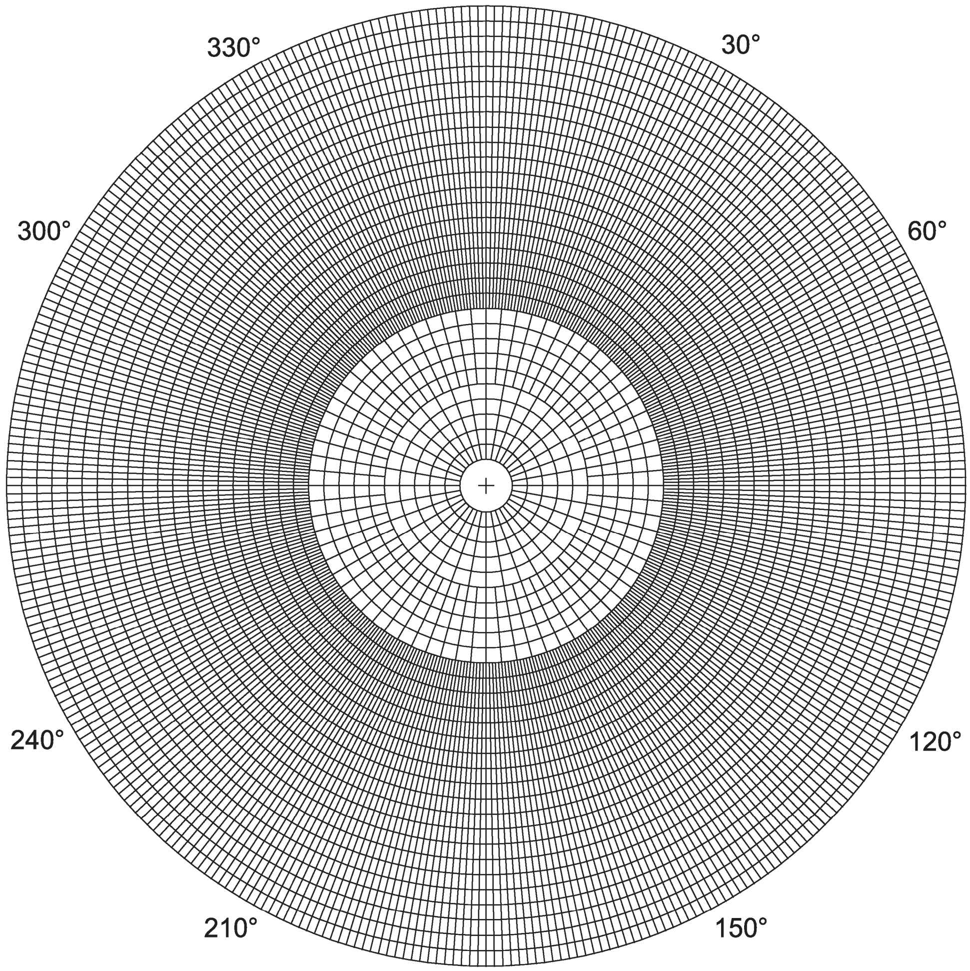
Step 4: Record the trial unbalance from above. ________________ g-mm (oz-in.)

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

A correlation has now been made between the units on the polar chart and the actual balance.

Figure C.1—Residual Unbalance Worksheet



The circle drawn shall contain the origin of the polar chart. If it does not, 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 the circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale chosen in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and center of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance ____ (g-mm) (oz-in.)

Record allowable residual unbalance (from Figure C.1) _________________________ (g-mm) (oz-in.)

Correction plane __________________ for rotor no. _____________________ (has/has not) passed

By ____ Date ________________________________

Figure C.1—Residual Unbalance Worksheet (Continued)

Equipment (rotor) no.: C-101

Purchase order no.: ________

Correction plane (inlet, drive end, etc.—use sketch): A

Balancing speed: 800 r/min

n = maximum allowable rotor speed: 10,000 r/min

m = mass of journal (closest to this correction plane): 908 ~~kg~~ (lb)

U_{max} = maximum allowable residual unbalance =

6350 m/n (4 m/n)

~~6350 × ______ kg/______ r/min~~; (4 × 908 lb/10,000 r/min) 0.36 ~~g-mm~~(oz-in.)

Trial unbalance (2 × U_{max}) 0.72 ~~g-mm~~ (oz-in.)

R = radius (at which mass shall be placed): 6.875 ~~mm~~ (in.)

Trial unbalance mass = Trial unbalance/R

~~_____g-mm/_____mm~~ 0.72 oz-in./ 6.875 in. 0.10 ~~g~~ (oz)

Conversion Information: 1 ounce = 28.350 grams

Test Data **Rotor Sketch**

Position	Trial Mass Angular Location	Balancing Machine Amplitude Readout
1	0°	14.0
2	60°	12.0
3	120°	14.0
4	180°	23.5
5	240°	23.0
6	300°	15.5
Repeat 1	0°	13.5

Test Data—Graphic Analysis

Step 1: Plot data on the polar chart (Figure C.2 continued). Scale the chart so the largest and smallest amplitudes fit 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. 35 units

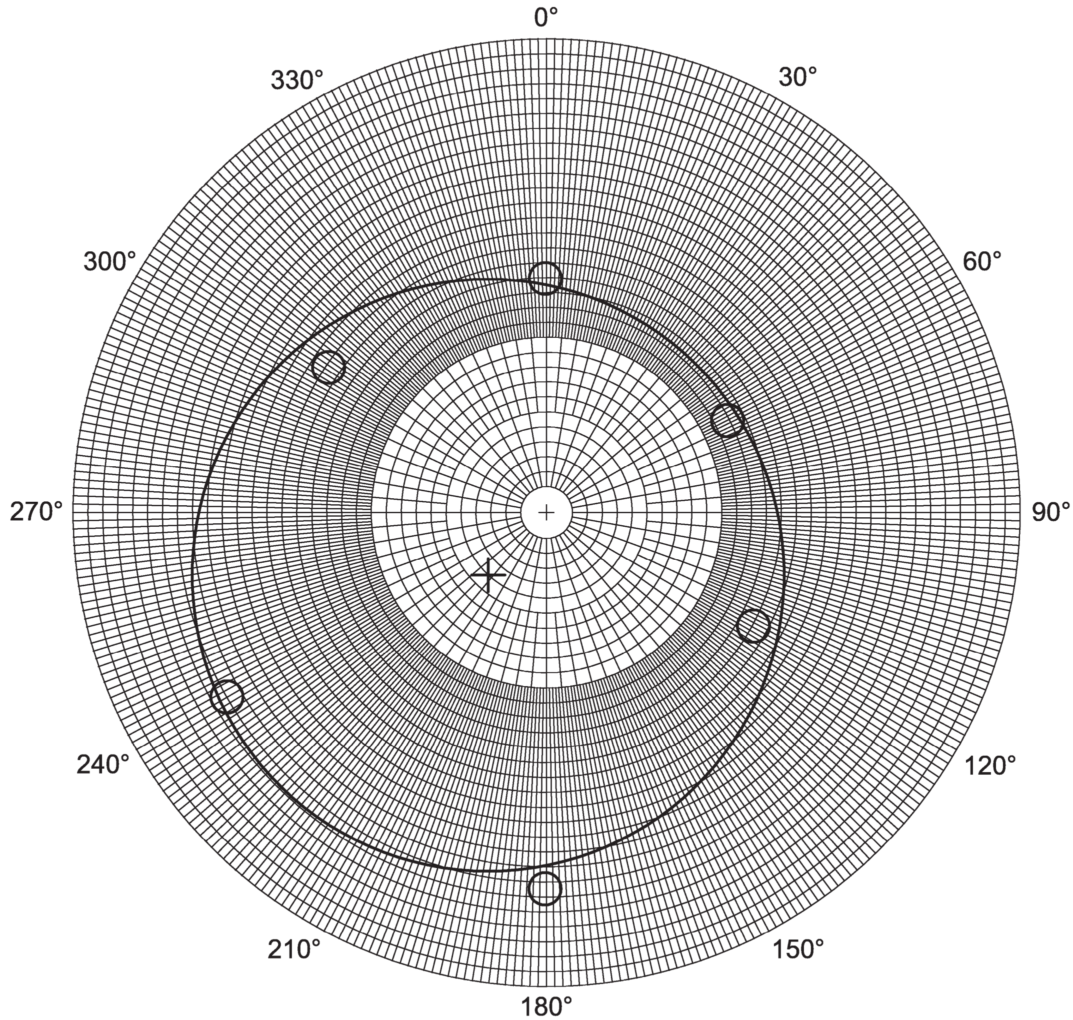
Step 4: Record the trial unbalance from above. 0.72 ~~g-mm~~ (oz-in.)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). 1.44 ~~g-mm~~ (oz-in.)

Step 6: Divide the answer in Step 5 by the answer in Step 3. 0.041 Scale factor

A correlation has now been made between the units on the polar chart and the actual balance.

Figure C.2—Sample Calculations for Residual Unbalance



The circle you have drawn shall contain the origin of the polar chart. If it does not, 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 chosen 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 5 (0.041) = 0.21 (~~g-mm~~) (oz-in.)

Record allowable residual unbalance (from Figure C.1) 0.36 (~~g-mm~~) (oz-in.)

Correction plane A for rotor no. C-101 (has/~~has not~~) passed.

By John Inspector Date 11-31-94

Figure C.2—Sample Calculations for Residual Unbalance (Continued)

Annex D
(normative)

Calculation of the Maximum Rotor Speed During an Overspeed Trip

D.1 Scope

D.1.1 Following the initiation of a trip by the overspeed trip system, the speed of the rotor system will increase due to the following.

a) The energy input to the turbine during the signal delay time, T_S. This delay includes the response time of the electronic overspeed trip device as well as the response time of all the components between the electronic overspeed trip device and the steam trip valve such as the hydraulic trip block, hydraulic piping runs, and solenoid valves. The power input corresponds to the maximum turbine power.

b) The energy input to the turbine during the stop valve(s) closing time, T_V. This power input corresponds to a certain fraction (f) of the maximum turbine power. For example, for a valve with a linear response characteristic, $f = 0.5$.

c) The energy input to the turbine from any steam (or condensate that can flash to steam) contained within the turbine system when the turbine is operating at maximum output. The steam will expand to the exhaust pressure. The power from this source may be partly or wholly expanded during the time the stop valve is closing or after the valve has become closed if the steam is trapped in a region downstream of the stop valve such as extraction piping. It is assumed that a certain fraction of this power is available for accelerating the rotor system.

The Peak Kinetic Energy of the rotor is the starting kinetic energy at overspeed trip set point plus all the energy input to the rotor during the period between the initiation of a trip and the final closure of the stop valve(s). The final speed can be calculated using the Peak Kinetic Energy and inertia of the rotor. See Figure D.1.

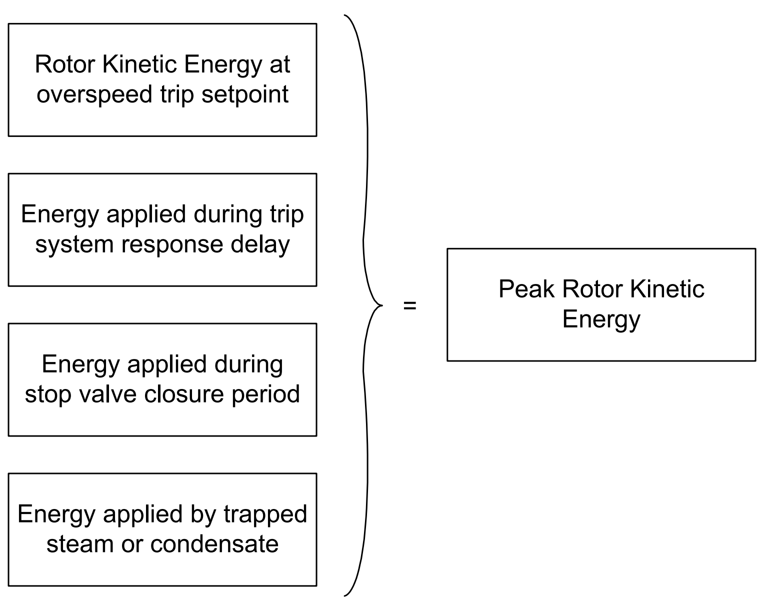


Figure D.1—Peak Kinetic Energy of the Rotor

D.1.2 The maximum speed attained by the rotor, N_{max}, may be determined by evaluating the rotor energy at the time the trip is initiated, then adding the energy that is applied to the rotor by the steam until the energy sources are removed and dissipated. These calculations will tend to be conservative (actual excursion should be less than the calculated excursion) because the energy consumed by the parasitic losses (bearing friction, windage) has not been subtracted from the total energy of the rotor after the trip sequence is initiated. The accuracy of these calculations can be improved if these losses are included.

D.2 Calculations in SI Units

a) The instantaneous rotor acceleration at the overspeed trip setting can be determined by

$$\alpha_t = k \times \frac{P_{g(max)}}{N_T \times WR^2} \quad \text{(rpm/s)} \tag{D.1}$$

$$\alpha_t = k \times \frac{P_{g(max)}}{N_T \times WR^2{}_C} \quad \text{(rpm/s)} \tag{D.2}$$

where

k equals 9.12 × 10^4 [rpm^2-kg-m^2/(kW-s)];

$P_{g(max)}$ is the turbine rated power (kW);

N_T is the set point of overspeed trip device (rpm);

WR^2 is the rotational inertia a rotor (kg-m^2);

$WR^2{}_T$ is the rotational inertia of turbine rotor (uncoupled) (kg-m^2);

$WR^2{}_C$ is the rotational inertia of the complete train (kg-m^2).

b) The kinetic energy of the rotor at a given speed, N, can be calculated by

$$E = k_2 \times WR^2 \times N^2 \quad \text{(kW-s)} \tag{D.3}$$

$$E_T = k_2 \times WR^2 \times N_T{}^2 \quad \text{(kW-s)} \tag{D.4}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 \quad \text{(kW-s) (complete train)} \tag{D.5}$$

where

E_T is the rotor kinetic energy at overspeed trip set point;

k_2 equals 5.49 × 10^{-6} [kW-s-min^2/(kg-m^2)].

c) The energy added to the rotor during the signal delay time is

$$\Delta E_s = T_s \times P_{g(max)} \quad \text{(kW-s)} \tag{D.6}$$

where

T_s is the signal time delay (seconds).

d) The energy added to the rotor during the closure time of the stop valve is

$$\Delta E_{\mathrm{v}} = f \times T_{\mathrm{v}} \times P_{\mathrm{g(max)}} \quad \text{(kW-s)} \tag{D.7}$$

where

T_{v} is the closure time for stop valve (seconds);

f is the fraction of maximum steam flow that passes through the stop valve during closure period.

If the stop valve characteristics are linear, the energy added during the closure time of the stop valve would be half the turbine max power times the closure time. In this case, f would be 0.5.

e) The energy added to the rotor by the expansion of steam that is trapped within the turbine is

$$\Delta E_{\mathrm{e}} = k_3 \eta \left[\sum W_{1\mathrm{i}} u_{1\mathrm{i}} - \sum W_{2\mathrm{i}} u_{2\mathrm{i}} - \sum (W_{1\mathrm{i}} - W_{2\mathrm{i}}) h_{2\mathrm{i}} \right] \quad \text{(kW-s)} \tag{D.8}$$

where

k_3 equals 1.0 kW-s/kJ

η is the steam turbine efficiency;

$W_{1\mathrm{i}}$ is the mass of steam and condensate contained within each “i” space inside the turbine when the turbine is operating at its maximum output (kg);

$u_{1\mathrm{i}}$ is the internal energy for each of the steam $W_{1\mathrm{i}}$ masses, estimated at the actual pressures and temperatures that exist at the various “i” spaces when operating at maximum output (kJ);

$W_{2\mathrm{i}}$ is the weight of steam in the “i” spaces defined for $W_{1\mathrm{i}}$ after expansion has ceased (kg);

$u_{2\mathrm{i}}$ is the internal energies for the $W_{2\mathrm{i}}$ masses of steam in the “i” spaces after isentropic expansion (kJ);

$h_{2\mathrm{i}}$ is the enthalpies of the $W_{2\mathrm{i}}$ masses of steam after isentropic expansion.

f) The maximum kinetic energy of the rotor will be the sum of the kinetic energy at the time the overspeed trip system initiates a trip and the energy added due to time delays and entrapped steam.

$$E_{\mathrm{max}} = E_{\mathrm{T}} + E_{\mathrm{s}} + E_{\mathrm{v}} + E_{\mathrm{e}} \quad \text{(kW-s)} \tag{D.9}$$

g) The maximum speed attained by the rotor can be calculated using Equations (D.3) and (D.4) as follows.

$$N_{\mathrm{max}} = \sqrt{\frac{E_{\mathrm{max}} \times 10^6}{k_2 \times \mathrm{WR}^2{}_{\mathrm{T}}}} \quad \text{(rpm) (turbine uncoupled)} \tag{D.10}$$

$$N_{\mathrm{max}} = \sqrt{\frac{E_{\mathrm{max}} \times 10^6}{k_2 \times \mathrm{WR}^2{}_{\mathrm{C}}}} \quad \text{(rpm) (complete train)} \tag{D.11}$$

D.3 Calculations in USC Units

D.3.1 Generator Drive

a) The instantaneous rotor acceleration at the overspeed trip setting can be determined by

$$\alpha_t = k \times \frac{P_{g(max)}}{N_T \times WR^2} \quad \text{(rpm/s)} \tag{D.12}$$

where

k equals 2.164 × 10^6 rpm^2-lb-ft^2/(kW-s)

$P_{g(max)}$ is the turbine rated power (kW);

N_T is the set point of overspeed trip device (rpm);

WR^2 is the rotational inertia of a rotor (lb-ft^2);

$WR^2{}_T$ is the rotational inertia of turbine rotor (uncoupled) (lb-ft^2);

$WR^2{}_C$ is the rotational inertia of the complete train (lb-ft^2).

b) The kinetic energy of the rotor at a given speed, N, can be calculated by

$$E = k_2 \times WR^2 \times N^2 \quad \text{(kW-s)} \tag{D.13}$$

$$E_T = k_2 \times WR^2 \times N_T{}^2 \quad \text{(kW-s) (turbine uncoupled)} \tag{D.14}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 \quad \text{(kW-s) (complete train)} \tag{D.15}$$

where

E_T is the rotor kinetic energy at overspeed trip set point;

k_2 equals 2.31 × 10^{-7} [kW-s-min^2/(lb-ft^2)]

c) The energy added to the rotor during the signal delay time is

$$\Delta E_s = T_s \times P_{g(max)} \quad \text{(kW-s)} \tag{D.16}$$

where

T_s is the signal time delay (seconds).

d) The energy added to the rotor during the closure time of the stop valve is

$$\Delta E_v = f \times T_v \times P_{g(max)} \quad \text{(kW-s)} \tag{D.17}$$

where

T_v is the closure time for stop valves (seconds);

f is the fraction of the maximum turbine output during the stop valve closure period.

Stop valves typically have characteristics that result in f being less than 1 but greater than 0.5. The stop valve manufacturer may furnish typical values of f for the valve in question.

e) The energy added to the rotor by the expansion of steam that is trapped within the turbine is

$$\Delta E_e = k_3 \eta \left[\sum W_{1i} u_{1i} - \sum W_{2i} u_{2i} - \sum (W_{1i} - W_{2i}) h_{2i} \right] \text{ (kW-s)} \qquad \text{(D.18)}$$

where

k_3 equals 1.055 kW-s/BTU;

η is the steam turbine efficiency;

W_{1i} is the mass of steam and condensate contained within each “i” space inside the turbine when the turbine is operating at its maximum output (lbm);

u_{1i} is the internal energy for each of the steam W_{1i} masses, estimated at the actual pressures and temperatures that exist at the various “i” spaces when operating at maximum output (BTU/lbm);

W_{2i} is the weight of steam in the “i” spaces defined for W_{1i} after expansion has ceased (lbm);

u_{2i} is the internal energies for the W_{2i} masses of steam in the “i” spaces after isentropic expansion (BTU/lbm);

h_{2i} is the enthalpies of the W_{2i} masses of steam after isentropic expansion (BTU/lbm).

f) The maximum kinetic energy of the rotor will be the sum of the kinetic energy at the time the overspeed trip system initiates a trip and the energy added due to time delays and entrapped steam.

$$E_{max} = E_T + E_s + E_v + E_e \text{ (kW-s)} \qquad \text{(D.19)}$$

g) The maximum speed attained by the rotor can be calculated using Equations (D.14) and (D.15), as follows.

$$N_{max} = \sqrt{\frac{E_{max} \times 10^6}{k_2 \times \mathrm{WR}^2}} \text{ (rpm) (turbine uncoupled)} \qquad \text{(D.20)}$$

$$N_{max} = \sqrt{\frac{E_{max} \times 10^6}{k_2 \times \mathrm{WR}^2{}_C}} \text{ (rpm) (complete train)} \qquad \text{(D.21)}$$

D.3.2 Mechanical Drive

a) The instantaneous rotor acceleration at the overspeed trip setting can be determined by

$$\alpha_t = k \times \frac{P_{g(max)}}{N_T \times WR^2} \text{ (rpm/s) (turbine uncoupled)} \quad \text{(D.22)}$$

$$\alpha_c = k \times \frac{P_{g(max)}}{N_T \times WR^2{}_C} \text{ (rpm/s) (turbine coupled)} \quad \text{(D.23)}$$

where

k equals 1.614×10^6 rpm^2-lb-ft^2/(hp-s);

$P_{g(max)}$ is the turbine rated power (hp);

N_T is the set point of overspeed trip device (rpm);

$WR^2{}_T$ is the rotational inertia of turbine (uncoupled) (lb-ft^2);

$WR^2{}_C$ is the rotational inertia of the complete train (coupled) (lb-ft^2).

b) The kinetic energy of the rotor at a given speed, N, can be calculated by

$$E = k_2 \times 10^{-7} \times WR^2 \times N^2 \text{ (hp-s)} \quad \text{(D.24)}$$

$$E_T = k_2 \times WR^2 \times N_T{}^2 \text{ (hp-s) (turbine uncoupled)} \quad \text{(D.25)}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 \text{ (hp-s) (complete train)} \quad \text{(D.26)}$$

where

E_T is the rotor kinetic energy at overspeed trip set point;

K_2 equals 3.10×10^{-7} [hp-s-min^2/(lb-ft^2)].

c) The energy added to the rotor during the signal delay time is

$$\Delta E_s = T_s \times P_{g(max)} \text{ (hp-s)} \quad \text{(D.27)}$$

where

T_s is the signal time delay (seconds).

d) The energy added to the rotor during the closure time of the stop valve is

$$\Delta E_v = f \times T_v \times P_{g(max)} \text{ (hp-s)} \quad \text{(D.28)}$$

where

T_{v} is the closure time for stop valve (seconds);

f is the fraction of maximum steam flow that passes through the stop valve during closure period.

If the stop valve characteristics are linear, the energy added during the closure time of the stop valve would be half the turbine max power times the closure time. In this case, f would be 0.5.

e) The energy added to the rotor by the expansion of steam that is trapped within the turbine is

$$\Delta E_{\text{e}} = k_3\eta\left[\sum W_{1\text{i}}u_{1\text{i}} - \sum W_{2\text{i}}u_{2\text{i}} - \sum (W_{1\text{i}} - W_{2\text{i}})h_{2\text{i}}\right] \text{ (hp-s)} \quad \text{(D.29)}$$

where

k_3 equals 1.415 hp-s/BTU;

η is the steam turbine efficiency;

$W_{1\text{i}}$ is the mass of steam and condensate contained within each “i” space inside the turbine when the turbine is operating at its maximum output;

$u_{1\text{i}}$ is the internal energy for each of the steam $W_{1\text{i}}$ masses, estimated at the actual pressures and temperatures that exist at the various “i” spaces when operating at maximum output;

$W_{2\text{i}}$ is the weight of steam in the “i” spaces defined for $W_{1\text{i}}$ after expansion has ceased;

$u_{2\text{i}}$ is the internal energies for the $W_{2\text{i}}$ masses of steam in the “i” spaces after isentropic expansion;

$h_{2\text{i}}$ is the enthalpies of the $W_{2\text{i}}$ masses of steam after isentropic expansion.

f) The maximum kinetic energy of the rotor will be the sum of the kinetic energy at the time the overspeed trip system initiates a trip and the energy added due to time delays and entrapped steam.

$$E_{\text{max}} = E_{\text{T}} + E_{\text{s}} + E_{\text{v}} + E_{\text{e}} \text{ (hp-s)} \quad \text{(D.30)}$$

g) The maximum speed attained by the rotor can be calculated using Equations (D.25) and (D.26), as follows.

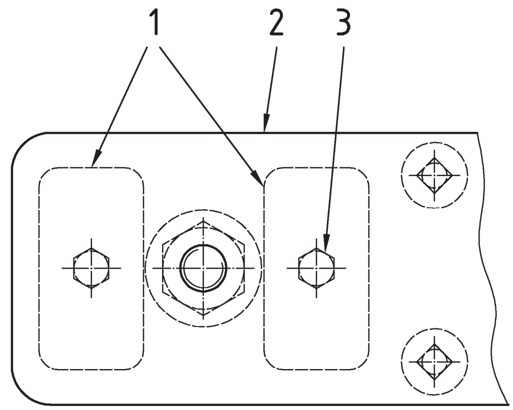
$$N_{\text{max}} = \sqrt{\frac{E_{\text{max}} \times 10^6}{k_2 \times \text{WR}^2{}_{\text{T}}}} \text{ (rpm) (turbine uncoupled)} \quad \text{(D.31)}$$

$$N_{\text{max}} = \sqrt{\frac{E_{\text{max}} \times 10^6}{k_2 \times \text{WR}^2{}_{\text{C}}}} \text{ (rpm) (complete train)} \quad \text{(D.32)}$$

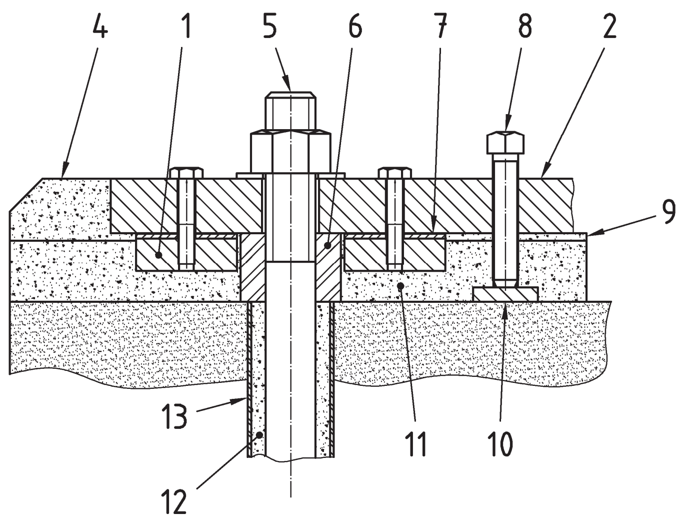
Annex E
(informative)

Mounting Plate Arrangements

See Figure E.1, Figure E.2, Figure E.3, and Figure E.4.



a) Top View of Foundation at Foundation Bolt

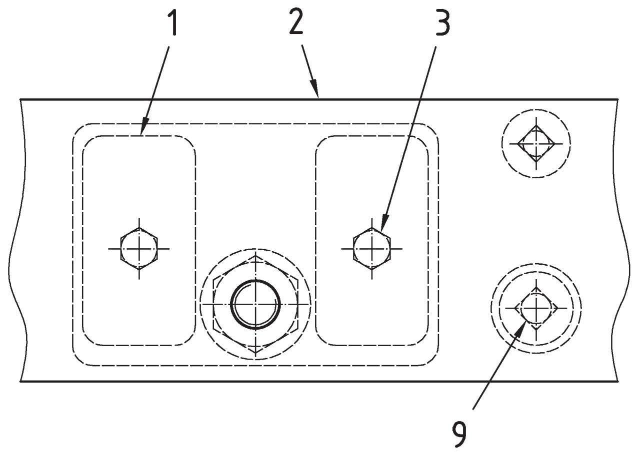


b) Cross Section of Foundation at Foundation Bolt

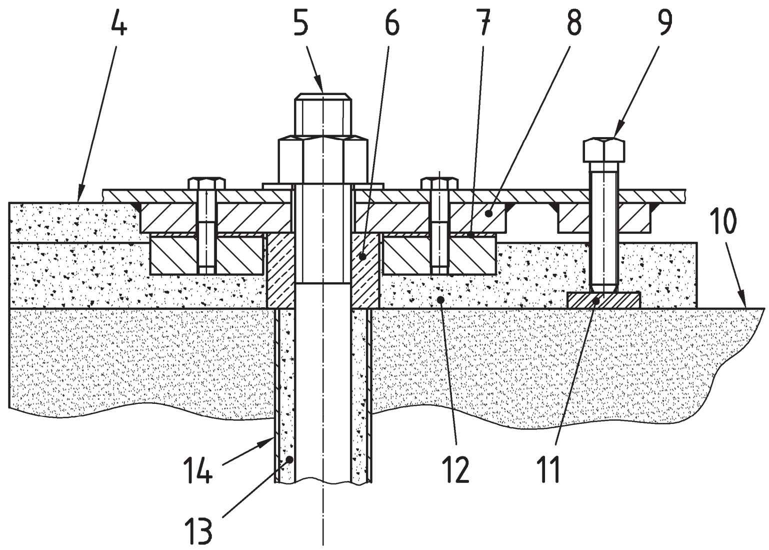
Key

1 subplate
2 soleplate
3 capscrew
4 final grout level after shimming is complete
5 anchor bolt
6 anchor bolt sleeve grout seal
7 shims
8 leveling jackscrew
9 grout level for shim access
10 leveling plate
11 epoxy grout
12 nonbonding fill
13 anchor bolt sleeve

Figure E.1—Typical Mounting Plate Arrangement—Soleplate with Subplate



a) Top View of Foundation at Foundation Bolt

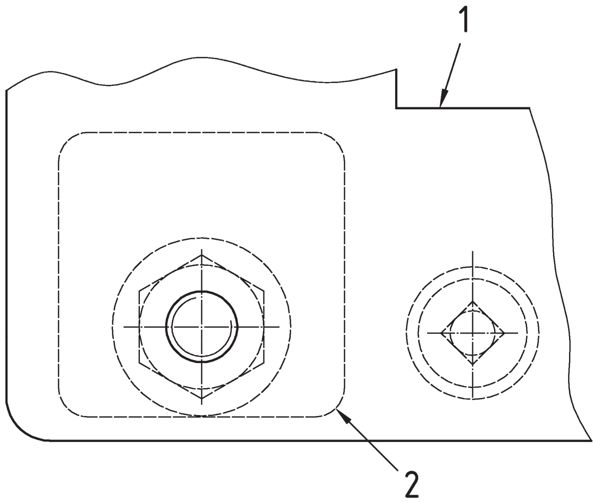


b) Cross Section of Foundation at Foundation Bolt

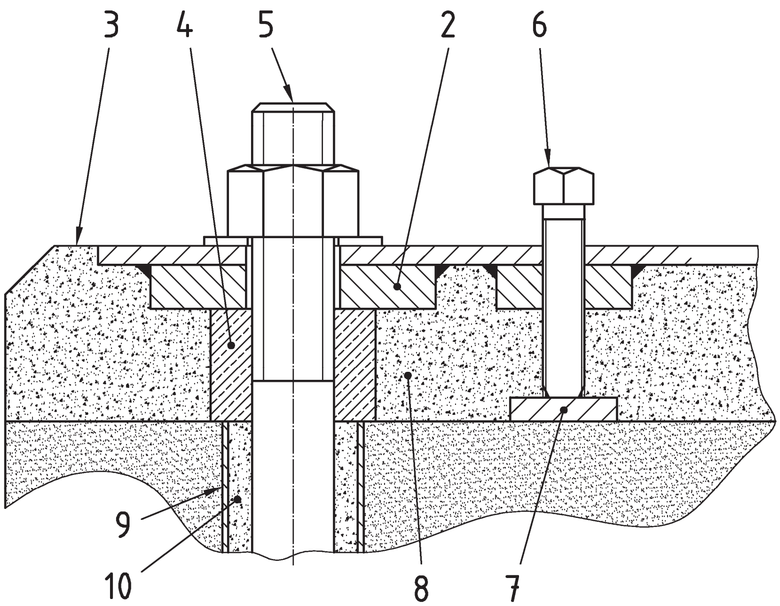
Key

1 subplate
2 baseplate beam
3 capscrew
4 optional full bed grout level after shimming is complete
5 anchor bolt
6 anchor bolt sleeve grout seal
7 shims
8 baseplate mounting pad
9 leveling jackscrew
10 grout level for shim access
11 leveling plate
12 epoxy grout
13 nonbonding fill
14 anchor bolt sleeve

Figure E.2—Typical Mounting Plate Arrangement—Baseplate with Subplate



a) Top View of Foundation at Foundation Bolt

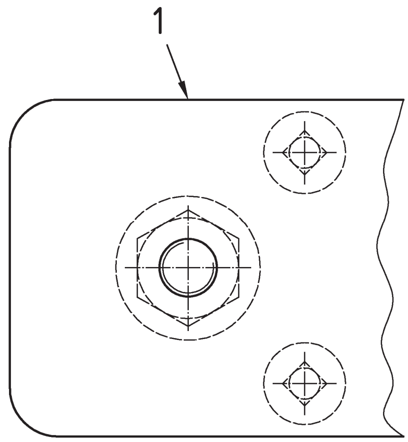


b) Cross Section of Foundation at Foundation Bolt

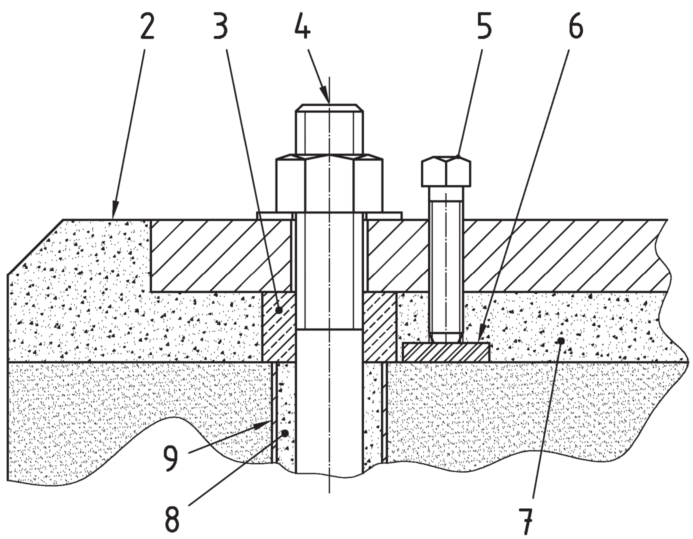
Key

1 baseplate beam
2 baseplate mounting pad
3 grout level
4 anchor bolt sleeve grout seal
5 anchor bolt
6 leveling jackscrew
7 leveling plate
8 epoxy grout
9 anchor bolt sleeve
10 nonbonding fill

Figure E.3—Typical Mounting Plate Arrangement—Baseplate Without Subplates



a) Top View of Foundation at Foundation Bolt



b) Cross Section of Foundation at Foundation Bolt

Key

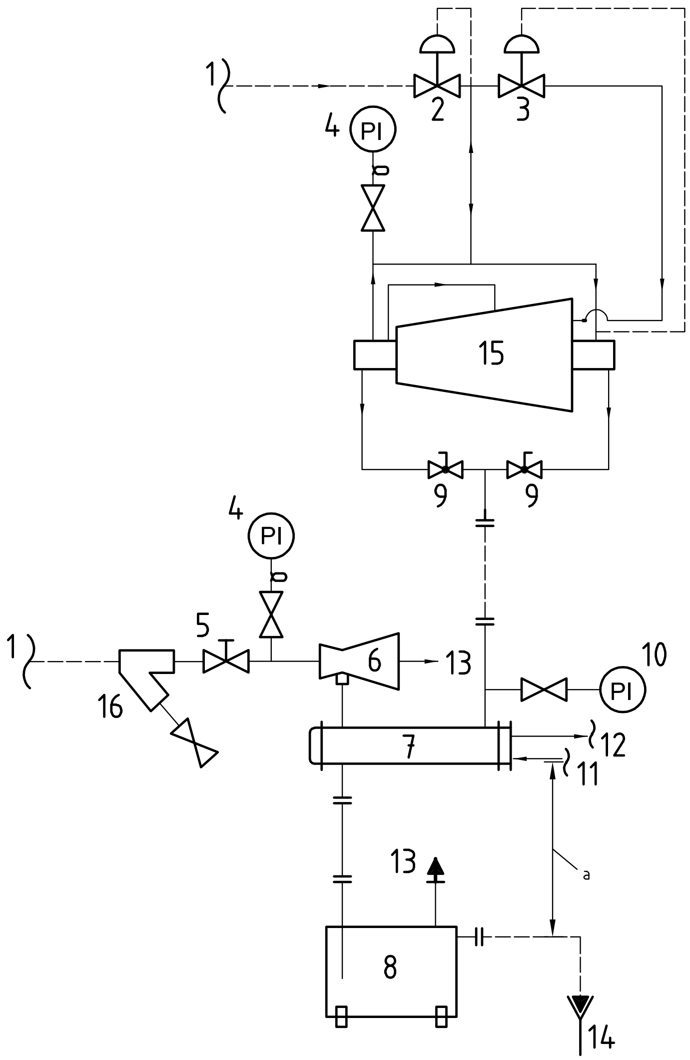
1	soleplate	4	anchor bolt	7	epoxy grout
2	grout level	5	leveling jackscrew	8	nonbonding fill
3	anchor bolt sleeve grout seal	6	leveling plate	9	anchor bolt sleeve

Figure E.4—Typical Mounting Plate Arrangement—Soleplate Without Subplates

Annex F
(informative)

Gland Sealing and Leak-off System

See Figure F.1 and Figure F.2.

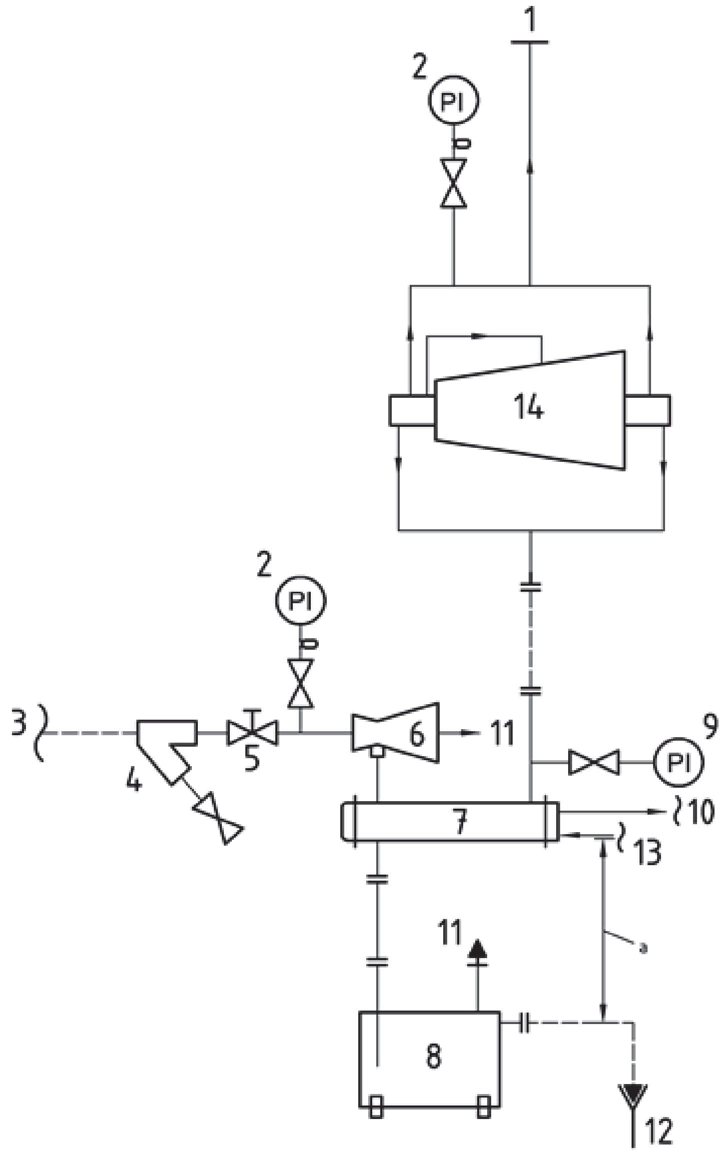


Key

1	dry steam supply	7	gland condenser	12	cooling water return
2	pressure reducing valve	8	condensate seal tank	13	vent
3	back-pressure regulator	9	flow adjusting valve (only if specified)	14	drain
4	pressure gauge	10	vacuum gauge	15	turbine
5	flow-control valve	11	cooling water supply	16	steam strainer
6	air ejector (vacuum pump if specified)		———— Vendor supply		-------- Purchaser supply

[a] ≥ 900 mm (3 ft).

Figure F.1—Typical Gland Sealing and Leak-off System for Condensing Turbines



Key

1 low pressure steam header
2 pressure gauge
3 dry steam supply
4 steam strainer
5 flow-control valve
6 air ejector (vacuum pump if specified)
7 gland condenser
8 condensate receiver
9 vacuum gauge
10 cooling water return
11 vent
12 drain
13 cooling water supply
14 turbine

[a] ≥ 900 mm (3 ft).

————————	Vendor supply
- - - - - - - - - - - - -	Purchaser supply

Figure F.2—Typical Gland Leak-off System for Back-pressure Turbines

Annex G
(informative)

Typical Inspection of Components

See Table G.1.

Table G.1—Component Inspection

<table>
<tr><th>Type</th><th>Component</th><th>Mechanical Property Analysis</th><th>Chemical Analysis</th><th>Ultrasonic Test</th><th>Local X-ray Test</th><th>Test for Surface Cracks</th></tr>
<tr><td rowspan="3">Forged or rolled components</td><td>Wheel discs
Shaft
Balance pistons</td><td>Yes [a]</td><td>Product check analysis or cast analysis [a]</td><td>Yes</td><td>NR</td><td>Yes</td></tr>
<tr><td>Stationary blade Carriers
Steel casing</td><td>Yes [a]</td><td></td><td colspan="2">NR</td><td>Yes [b]</td></tr>
<tr><td>Rotor blades
Guide blades</td><td colspan="2">Yes [a]</td><td colspan="2">NR</td><td>NR</td></tr>
<tr><td rowspan="2">Welded components</td><td>Wheel discs
Stationary blade Carriers</td><td>Yes [a]</td><td>Yes</td><td colspan="2">If specified [c]</td><td>Yes, in welded areas</td></tr>
<tr><td>Steel casings</td><td>Yes [a]</td><td>Yes</td><td rowspan="2">Yes
For gauge pressure
> 6200 kPa (900 psi) or temperature
> 440 °C (825 °F)</td><td rowspan="2">Yes [d]
For gauge pressure
> 8600 kPa (1250 psi) or temperature
> 510 °C (950 °F)</td><td>Yes</td></tr>
<tr><td rowspan="3">Castings</td><td>Steel casings</td><td rowspan="2">Yes</td><td rowspan="2">Product check analysis or cast analysis [a]</td><td rowspan="2">Yes (on machined surfaces)</td></tr>
<tr><td>Guide blade carriers</td><td>Yes</td><td>If specified</td></tr>
<tr><td>Rotor blades</td><td colspan="2">Yes [a]</td><td>If specified [c]</td><td>Random checks</td><td>Footnote [c]</td></tr>
</table>

a Per lot.

b Typical surface magnetic particle inspection.

c The details of testing shall be agreed between purchaser and vendor.

d Where practical on larger components.

Annex H
(informative)

Inspector's Checklist

See Table H.1.

Table H.1—Inspector's Checklist

Item	Reference Subsection	Reviewed	Observed	Witnessed	Inspected By	Status
General						
Vendor data records	16.2.1.1					
Final assembly maintenance and clearances	16.2.1.1 f)					
Surface and subsurface inspection	16.2.1.3					
Material Inspection						
Material inspection certification/testing	16.2.2					
Mechanical Inspection						
Stud markings	7.1.15 d)					
Socket clearances	7.1.15 e)					
Equipment feet (vertical and horizontal) jackscrews	7.1.18 15.2.1.2.1					
Foot/baseplate shims	15.2.1.2.2					
Nozzle flange dimensions	7.2.6					
Casing openings—size/finish	7.2.3 7.2.6					
Rotor identification	8.1.3					
Number of teeth for governor and overspeed shutdown system wheel	8.4 12.2.7					
Shaft finishes	8.2.1, 8.2.2					
Shaft electrical and mechanical runout	8.2.2 9.7.9					
Shaft magnetic flux density	8.2.5					
Coupling shaft end design	8.2.4					
Rotor balance (balance machine residual)	9.7					
Rotation arrow/nameplate data and units	6.2.2 6.2.3					
Mounting surfaces coated	15.2.1.2.20					
Mounting surfaces primed	15.2.1.2.18					
Oil system cleanliness	16.2.3.2					
Equipment cleanliness	16.2.3.3					
Material hardness	16.2.3.4					

Table H.1—Inspector's Checklist (Continued)

Item	Reference Subsection	Reviewed	Observed	Witnessed	Inspected By	Status
Mechanical Running Test						
Contract shaft seals and bearings	16.3.3.1 a)					
Oil flows, pressure, and temperature as specified	16.3.3.1 b)					
No leaks observed	16.3.3.1 d)					
Protective devices operational	16.3.3.1 e)					
Control devices operational	16.3.3.1 e)					
Control instrumentation used	16.3.3.1 g)					
Control system functional at specified speeds	16.3.3.2					
Four-hour test complete	16.3.3.2 f)					
Lateral critical speeds as predicted	16.3.3.3 c)					
Recordings complete	16.3.3.3 e)					
Bearing inspection after test satisfactory	16.3.3.4					
Spare rotor fit and run	16.3.3.4 c)					
Optional Tests						
Performance test	16.3.4.2					
Complete unit test	16.3.4.3					
Auxiliary equipment test	16.3.4.4					
Post-test casing internal inspection	16.3.4.5					
Overspeed shutdown systems test	16.3.4.6					
Spare parts test	16.3.4.8					
Turning gear test	15.8					
Preparation for Shipment						
Preparation complete	16.4.1					
Paint	16.4.3 a)					
Rust preventative (exterior and interior)	16.4.3 b) 16.4.3 c)					
Tagging complete	16.4.3 i) 16.4.5					
Installation instructions shipped	16.4.6					
Special tools complete	15.9.2					
Spare parts complete	17.3.4.2					
Studs installed	7.1.14					

Annex I
(informative)

Vendor Drawing and Data Requirements (VDDR)

I.1 Example VDDR Form

Special-purpose Steam Turbine Vendor Drawing and Data Requirement

Job No. ____________ Item No. ____________
Purchase Order No. ____________ Date: ____________
Requisition No. ____________ Date: ____________
Enquiry No. ____________ Date: ____________
Page ______ of ______ By ____________
Revision ____________
Unit ____________
No. Required ____________

For ____________
Site ____________
Service ____________

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

Review[b] Vendor shall furnish __ copies and ___ electronic copies of drawings and data indicated.

Final[c] Vendor shall furnish __ copies and ___ electronic copies of drawings and data indicated.
Vendor shall furnish __ operating and maintenance manuals.

Distribution record

Final – Received from vendor
Final – Due from vendor
Review – Returned from vendor
Review – Received from vendor
Review – Due from vendor

				Description					
			a)	Certified dimensional outline drawing and list of connections					
			b)	Cross-sectional drawing and bill of materials					
			c)	Rotor assembly drawings and bills of materials					
			d)	Thrust-bearing assembly drawing and bill of materials					
			e)	Journal-bearing assembly drawings and bills of materials					
			f)	Seal assembly drawing and bill of materials					
			g)	Shaft coupling assembly drawing and bill of materials					
			h)	Gland sealing and leak-off schematic and bill of materials					
			i)	Gland sealing and leak-off arrangement drawing and list of connections					
			j)	Gland sealing and leak-off component drawings and data					
			k)	Lube oil schematics and bill of materials					
			l)	Lube oil system arrangement drawing and list of connections					
			m)	Lube oil component drawings and data					
			n)	Electrical and instrumentation schematics and bills of materials					
			o)	Electrical and instrumentation arrangement drawings and lists of connections					
			p)	Control- and governor-system description and schematic					
			q)	Overspeed shutdown system description and schematic					
			r)	Curves showing steam flow versus horsepower (certified)					
			s)	Curve showing steam flow versus first-stage pressure (certified)					
			t)	Curves showing steam flow versus speed and efficiency (certified)					
			u)	Curve showing steam flow versus valve lift					
			v)	Curves showing extraction/induction performance (certified)					
			w)	Steam correction factors (certified)					
			x)	Blading vibration analysis					
			y)	Lateral critical speed analysis					
			z)	Torsional critical speed analysis					
			aa)	Transient torsional analysis					
			bb)	Anticipated thermal movements for major connections					
			cc)	Coupling alignment diagram					
			dd)	Welding procedures for fabrication and repair					
			ee)	Hydro test logs (certified)					
			ff)	Mechanical running test logs					
			gg)	Nondestructive test procedures					
			hh)	Mill test reports					
			ii)	Rotor balancing logs					

[a] Proposal drawings and data do not have to be certified or as built.
[b] Purchaser to indicate in this column the timeframe for submission of materials using the nomenclature given at the end of this form.
[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

Data Requirement

Job No. ____________________ Item No.______________________
Purchase Order No. ___________ Date: ________________________
Requisition No. ______________ Date: ________________________
Enquiry No. ________________ Date: ________________________
Page ____________of________________ By _______________
Revision ______________________________________
Unit ____
No. Required___________________________________

For_______________________________________
Site _______________________________________
Service ____________________________________

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

Review[b] Vendor shall furnish __ copies and ___ electronic copies of drawings and data indicated.

Final[c] Vendor shall furnish __ copies and ___ electronic copies of drawings and data indicated.
Vendor shall furnish __ operating and maintenance manuals.

Distribution record

Final – Received from vendor
Final – Due from vendor
Review – Returned from vendor
Review – Received from vendor
Review – Due from vendor

			Description					
			jj) Rotor combined mechanical and electrical runout					
			kk) As-built datasheets					
			ll) As-built dimensions and data					
			mm) Installation operation					
			nn) Operating and maintenance manuals					
			oo) List of spare parts					
			pp) Progress reports and delivery schedule					
			qq) Drawing list					
			rr) Shipping list					
			ss) List of special tools furnished for maintenance					
			tt) Technical data manual					
			uu) Preservation, packaging, and shipping procedures					
			vv) Rigging and lifting instructions					
			ww) Vibration-probe sensing area/shaft drawing					
			xx) Material safety datasheets (e.g. OSHA Form 174)					
			yy) Speed versus torque					
			zz) Exhaust steam temperature versus power					
			aaa) First stage pressure versus thrust					

[a] Proposal drawings and data do not have to be certified or as built.
[b] Purchaser to indicate in this column the timeframe for submission of materials using the nomenclature given at the end of this form.
[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

NOTE 1 The vendor (__________ shall) (_________ shall not) proceed with manufacturer upon receipt of the order. (Review of drawings is required in either case.)

NOTE 2 ____Send all drawings and data to:

NOTE 3 All drawings and data shall show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings and instructions necessary for field installation shall be forwarded with the shipment.

NOTE 4 All of the information indicated on the distribution schedule shall be received before final payment is made.

Nomenclature:

S Number of weeks prior to shipment

F Number of weeks after firm order

D Number of weeks after receipt of approved drawings

Vendor:____

Date:_________________ Vendor reference: _________________________

Signature: ____
(Signature acknowledges receipt of all instructions)

I.2 Description

A description of the components (see example VDDR form list in I.1) should be provided as follows.

a) Certified dimensional outline drawing and list of connections, including the following:

  1) size, rating, and location of all customer connections;

  2) approximate overall handling masses;

  3) overall dimensions, maintenance clearances, and dismantling clearances;

  4) shaft centerline height, denoting nominal shim dimension;

  5) dimensions of baseplates (if furnished), complete with diameter, number, and locations of bolt holes, thickness of the metal through which bolts will pass, and recommended clearance; centers of gravity; details for foundation design;

  6) direction of rotation.

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

  1) journal-bearing clearances and tolerances;

  2) axial rotor float;

  3) shaft end and internal labyrinth seal clearances and tolerances;

  4) axial position of wheels(s), blades relative to inlet nozzles or vanes of diaphragms, and tolerance allowed;

  5) radial clearances at blade tips.

c) Rotor assembly drawing and bills of materials, including the following:

  1) axial position from the active thrust-collar face to

    i) each wheel, inlet side (built-up rotors only),

    ii) each radial probe,

    iii) each journal-bearing centerline,

    iv) phase angle notch, and

    v) coupling face or end of shaft;

  2) thrust-collar assembly details, including the following:

    i) collar shaft, with tolerance;

    ii) concentricity (or axial runout) tolerance;

    iii) required torque for locknut;

    iv) surface finish requirements for collar faces; and

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

  3) dimensioned shaft ends for coupling mountings.

d) Thrust-bearing assembly drawing and bill of materials.

e) Journal-bearing assembly drawings and bills of materials.

f) Seal assembly drawing and bills of materials.

g) Shaft-coupling assembly drawings and bills of materials, including the following:

   1) hydraulic mounting procedure;

   2) shaft end gap and tolerance;

   3) coupling guards;

   4) thermal growth from a baseline of 15 °C (60 °F);

   5) make, size, and serial number of coupling;

   6) axial natural frequency over allowable spacer stretch (disc-type couplings);

   7) balance tolerance;

   8) coupling “pull-up” mounting dimension;

   9) idling adapter details.

h) Gland sealing and leak-off schematic and bill of materials, including the following:

   1) steady-rate and transient steam and air flows and pressures and temperatures;

   2) control-valve settings;

   3) utility requirements, including electrical, water, steam, and air;

   4) pipe and valve sizes;

   5) instrumentation, safety devices, and control schemes;

   6) bill of materials.

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

j) Gland sealing and leak-off component, and sectional drawings and data, including the following:

   1) gland-condenser outline drawing, bill of materials, and loop seal requirements;

   2) complete datasheets for condenser;

   3) air or water ejector drawing and performance curves;

   4) control valves and instrumentation;

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

k) Lube oil schematics and bills of materials, including the following:

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

2) control, alarm and trip settings (pressures and recommended temperatures);

3) supply temperature and heat loads at each use point at maximum load;

4) utility requirements, including electricity, water, and air;

5) pipe and valve size;

6) instrumentation, safety devices, and control schemes;

7) relief valve set points;

8) size and location of all restriction orifices (to be shown on schematic).

l) Lube oil system assembly and arrangement drawings, including size, rating, and location of all customer connections.

m) Lube oil component drawings and data, including the following:

1) 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, and

vi) completed datasheets for pumps and drivers;

2) coolers, filters, and reservoir:

i) outline drawings,

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

iii) complete data form for coolers;

3) instrumentation:

i) controllers,

ii) switches,

iii) control valves,

iv) gauges;

4) priced spare parts list(s) and recommendations.

n) Electrical and instrumentation schematics and bills of materials, including the following:

   1) vibration alarm and shutdown set points;

   2) bearing temperature alarm and shutdown set points;

   3) axial shaft position alarm and shutdown set points.

o) Electrical and instrumentation arrangement drawings and lists of connections.

p) Control and governor system description and schematic, including the following:

   1) valve-lift sequence on multi-valve turbines and final settings;

   2) control-lever and actuator setting;

   3) control-system drawings, including I/O definition;

   4) control setting instructions;

   5) control-oil, bill of materials, and steady state and transient flows and pressures at each use point;

   6) size and location of all restriction orifices (to be shown on schematic);

   7) governor bill of materials;

   8) control panel and operator interface devices;

   9) control logic diagram to describe system functionality, facilitate implementation of the control system, and develop operator training.

q) Overspeed shutdown system description, including schematic.

r) Curves showing steam flow versus horsepower at normal and rated speeds with normal steam conditions.

s) Curve showing steam flow versus first-stage pressure for multi-stage machines or versus nozzle-bowl pressure for single-stage machines at normal and rated speed with normal steam.

t) Curves showing steam flow versus speed and efficiency at normal steam conditions.

u) Curve showing steam flow versus valve lift.

v) Curves showing extraction/induction performance.

w) Steam-rate correction factors for the curves listed in Items r) to v) with off-design steam, as follows:

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

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

   3) speed from 80 % to 105 % in 5 % increments;

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

x) Blading vibration analysis data, including the following:

1) tabulation of all potential excitation sources, such as vanes, blades, nozzles, and critical speeds;

2) Campbell diagram for each stage;

3) Goodman diagram for each stage.

y) Lateral critical speed analysis report, including but not limited to the following:

1) complete description of the method used;

2) graphic display of critical speeds versus operating needs;

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

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

5) journal static loads;

6) stiffness and damping coefficients;

7) tilting-pad bearing geometry and configuration, including the following:

i) pad angle (arc) and number of pads;

ii) pivot offset;

iii) pad clearance (with journal radius, pad bore radius, and bearing-set bore radius); and

iv) preload.

z) Torsional critical speed analysis report, including but not limited to the following:

1) complete description of the method used;

2) graphic display of the mass elastic system;

3) tabulation identifying the mass moment and torsional stiffness of each component identified in the mass elastic system;

4) graphic display of exciting forces versus speed and frequency;

5) graphic display of torsional critical speeds and deflections (mode-shape diagram);

6) effects of alternative coupling on analysis.

aa) Transient torsional analysis for all units using synchronous starter/helper motors (mandatory) or driving synchronous generators (optional).

bb) Anticipated thermal movements referenced to a defined point for major connections referenced to a defined point.

cc) Coupling alignment diagram, including recommended coupling limits during operation. Note all shaft-end position changes and support growth from a referenced ambient temperature of 15 °C (60 °F) or another temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.

dd) Welding procedures for fabrication and repair.

ee) Certified hydro test logs.

ff) Mechanical running test logs, including but not limited to the following:

1) oil flows, pressures and temperatures;

2) vibration, including an x-y plot of amplitude and phase angle versus revolutions per minute during start-up and coast-down;

3) bearing metal temperatures;

4) observed critical speeds (for flexible rotors);

5) if specified, tape recordings of real-time vibration data;

6) control data [16.3.3.2 e)].

gg) Nondestructive test procedures and acceptance criteria as itemized on the purchase order datasheets or the vendor drawing and data requirements form.

hh) Certified mill test reports of items as agreed upon in the precommitment or preinspection meetings.

ii) Rotor balance logs, including a residual unbalance report in accordance with Annex C.

jj) Rotor combined mechanical and electrical.

kk) As-built datasheets.

ll) As-built dimensions (including nominal dimensions with design tolerances) and data for the following listed parts:

1) shaft or sleeve diameters at

i) thrust collar (for separate collars),

ii) each seal component,

iii) each wheel (for stacked rotors) or bladed disk,

iv) each interstage labyrinth, and

v) each journal bearing;

2) each wheel or disk bore (for stacked rotors) and outside diameter;

3) each labyrinth or seal-ring bore;

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

5) each journal-bearing inside diameter;

6) thrust-bearing concentricity (axial runout);

7) thrust-bearing, journal-bearing, and seal clearances;

8) metallurgy and heat treatment for

   i) shaft,

   ii) wheels or bladed disks,

   iii) thrust collar, and

   iv) blades, vanes, and nozzles.

mm) Installation manual describing the following (see 17.3.5.2):

1) storage procedures;

2) foundation plan;

3) grouting details;

4) setting equipment, rigging procedures, component masses, and lifting diagrams;

5) coupling alignment diagram [as specified in Item cc)];

6) piping recommendations, including allowable flange loads;

7) composite outline drawings for the driver/driven-equipment train, including anchor-bolt locations;

8) dismantling clearances.

nn) Operating and maintenance manuals describing the following (see 17.3.5.3):

1) start-up;

2) normal shutdown;

3) emergency shutdown;

4) operating limits or other operating restrictions and list of undesirable speeds;

5) lube oil recommendations and specifications;

6) routine operational procedures, including recommended inspection schedules and procedures;

7) instructions for

   i) disassembly and reassembly of rotor in casing;

   ii) rotor unstacking and restacking procedures;

   iii) disassembly and reassembly of journal bearings (for tilting-pad bearings, the instructions shall include “go/no-go” dimensions with tolerances for three-step plug gauges);

   iv) disassembly and reassembly of thrust bearing;

   v) disassembly and reassembly of seals (including maximum and minimum clearances);

   vi) disassembly and reassembly of thrust collar;

vii) wheel reblading procedures; and

viii) boring procedures and torque values;

8) performance data, including the following:

i) curves showing steam flow versus normal and rated power at rated speed, including extraction/induction curves when applicable;

ii) curve showing steam flow versus first stage pressure;

iii) curves showing steam flow versus speed and efficiency;

iv) curve showing steam flow versus valve lift;

v) curves showing extraction/induction;

vi) steam condition correction factors (prefer monograph);

vii) speed versus torque;

viii) exhaust steam temperature versus power; and

ix) first stage pressure versus thrust;

9) vibration analysis data, as specified in Items x) to aa);

10) as-built data, including the following:

i) as-built datasheets;

ii) as-built dimensions or data, including assembly clearances;

iii) hydro test logs, as specified in Item ee);

iv) mechanical running test logs, as specified in Item ff);

v) rotor balancing logs, as specified in Item ii);

vi) rotor mechanical and electrical runout at each journal, as specified in Item jj);

vii) physical and chemical mill certificates, as specified in Item hh); and

viii) test logs of all specified optional tests;

11) drawings and data, including the following:

i) certified dimensional outline drawing and list of connections,

ii) cross-sectional drawing and bill of materials,

iii) rotor assembly drawings and bills of materials,

iv) thrust-bearing assembly drawing and bill of materials,

v) journal-bearing assembly drawings and bills of materials,

vi) seal-component drawing and bill of materials,

vii) lube oil schematics and bills of materials,

viii) lube oil assembly drawing and list of connections,

ix) lube oil component drawings and data,

x) electrical and instrumentation assembly drawings and bills of material,

xi) electrical and instrumentation assembly drawings and list of connections,

xii) governor and control- and trip-system drawings and data,

xiii) trip/combined trip and throttle-valve construction drawings.

oo) Spare parts list with stocking level recommendations, in accordance with 17.3.4.2.

pp) Progress reports and delivery schedule, including vendor buyouts and milestones.

qq) Drawing list, including latest revision numbers and dates.

rr) Shipping list, including all major components that will ship separately.

ss) List of special tools furnished for maintenance.

tt) Technical data manual, including the following:

1) as-built purchaser datasheets, as specified in Item kk);

2) certified performance curves, as specified in Items r) to w);

3) drawings, in accordance with 17.3.2;

4) as-built assembly clearances;

5) spare parts list, in accordance with 17.3.4.2;

6) utility data;

7) vibration data, as specified in Item x);

8) reports, as specified in Items y) to aa), cc), ii), and ss);

9) datasheets (e.g. Annex A).

uu) Preservation, packaging, and shipping procedures.

vv) Recommended equipment rigging and lifting instructions [see 16.4.3 h)].

ww) Vibration-probe sensing area/shaft drawing that accurately locates sensing areas on the shaft axis that are not to be metallized, sleeved, or plated.

xx) Material safety datasheets (e.g. OSHA Form 174).

Annex J
(informative)

Typical Material Specifications

Table J.1 lists for information some typical materials used for various turbine components. There is no attempt to specify materials to more detail than their commercial material designation. Specific heat treatment, actual chemical analysis, and other specialized material properties are not addressed. Materials not shown in the annex, while they may not be typical, may or may not be acceptable for a particular application.

Table J.1—Typical Material Specifications for Major Component Parts

Part	Material	Specification	Form	Maximum Temperature °C (°F)
Inlet casing/steam chest/integral exhaust casing (noncondensing):				
Cast	Carbon steel	ASTM A216, Grade WCB [a]	Cast	413 (775)
	Cr-Mo steel	ASTM A217, Grade WC1	Cast	454 (850)
	1 1/4 Cr, 1/2 Mo steel	ASTM A217, Grade WC6	Cast	510 (950)
	2 1/4 Cr, 1 Mo steel	ASTM A217, Grade WC9	Cast	566 (1050)
Fabricated	Carbon steel	ASME SA-516, Grade 60 or 70	Plate	413 (775)
	Cr-Mo steel	ASTM A387, Grade 11, Class 2 ASTM A204, Grade B	Plate	482 (900) 454 (850)
	1 1/4 Cr, 1/2 Mo steel	ASTM A387, Grade 11	Plate	510 (950)
	2 1/4 Cr-1 Mo steel	ASTM A387, Grade 22, Class 2	Plate	566 (1050)
Exhaust casing for condensing:				
Cast	Carbon steel	ASTM A216, Grade WCB [a]	Cast	400 (750)
Fabricated	Carbon steel	ASME SA-516, Grade 60 or 70	Plate	413 (775)
Rotor:				
Shaft, built-up	Medium carbon steel	AISI 1040 ASTM A293, Class 1	Bar/forging	343 (650)
	Cr-Mo steel	ASTM A434, Class BC, Grade 4140/42	Bar/forging	371 (700)
	Ni-Cr-Mo steel, N & T	AISI 4340	Forging	427 (800)
	Ni-Mo-V steel	ASTM A470, Class 9	Forging	427 (800)
Shaft with integral disks	Ni-Mo-V steel	ASTM A470, Class 4	Forging	482 (900)
	Cr-Ni-Mo-V steel	ASTM A470, Class 7	Forging	388 (730)
	Cr-Mo-V steel	ASTM A470, Class 8	Forging	566 (1050)

Table J.1—Typical Material Specifications for Major Component Parts (Continued)

Part	Material	Specification	Form	Maximum Temperature °C (°F)
Disks (built-up rotors only)	Carbon steel	ASTM A285, Grade C	Plate	316 (600)
	Ni-Cr-Mo steel, Q & T	AISI 4340	Forging	427 (800)
	Steel	ASTM A471, Class 12	Forging	371 (700)
	Alloy steel	ASTM A572, Grade 50	Forging	371 (700)
	Steel	ASTM A471, Class 13 or 14	Forging	399 (750)
	Ni-Cr-Mo-V steel	ASTM A471, Class 4 or 6	Forging	399 (750)
Rotor blades	12 Cr steel	AISI 403	Plate or forging	
	12 Cr steel	ASTM A565, UNS No. S42200	Forging	
	12 Cr steel	ASTM A276, Type XM-30	Forging	
	Titanium	TI-6AL-4V, AMS 4928	Bar	
Diaphragm blades and nozzle	12 Cr steel	AISI 405	Plate or forging	
	12 Cr steel	AISI 410	Plate or forging	
Diaphragm centers and outer rings				
Fabricated	ASME code quality steel Carbon steel	ASME SA-516, Grade 60 ASTM A668, Class BH	Plate	345 (650) 413 (775)
	High strength alloy steel, Q & T	ASTM A5617, Grade F ASTM A829, Grade 8620	Plate	427 (800) 454 (850)
	Cr-Mo steel plate	ASTM A387, Grade 11, Class 2	Plate	482 (900)
	Stainless steel	ASTM A276, Type 405 AMS 5355 17-4PH CA6NM	Bar Cast Forging	510 (950) 316 (600)
	Stainless seel	ASTM A473, Type 410	Forging	538 (1000)
Cast	Ductile cast iron	ASTM A536, Grade 65-45-12	Cast	300 (550)
Bearing housings	Carbon steel	ASTM A216, Grade WCB [a]	Cast	400 (750)
	Carbon steel	ASME SA-516, Grade 60	Plate	345 (650)
Bearing retainers	Carbon steel	ASTM A216, Grade WCB [a]	Cast	400 (750)
	Carbon steel	ASME SA-516, Grade 60	Plate	345 (650)
Oil seals	Aluminum	ASTM B26, Alloy 443.0	Cast or plate	204 (400)

Table J.1—Typical Material Specifications for Major Component Parts (Continued)

Part	Material	Specification	Form	Maximum Temperature °C (°F)
Bearings	Tin-base Babbitt (89 % Sn)	ASTM B23, Alloy #2	Cast	
	Carbon steel	ASME SA-516, Grade 60	Plate or tube	345 (650)
	Copper alloy	Copper Development Assoc., Alloy No. 182	Wrought	
Labyrinth seals including tip seals	High leaded tin bronze castings (14 % Pb, 7 % Sn)	ASTM B584, Alloy C93800	Cast	427 (800)
	Stainless steel	AISI Type 405	Forging	538 (1000)
Shaft sleeves	Carbon steel tubing	SAE J5245	Tubing	400 (750)
	Ni-Cr-Mo steel	AISI 4340	Tubing	482 (900)
Stationary retainers	Ni-Cr-Mo steel, Q & T	AISI 4340		
Control valves	12 Cr steel	ASTM A565, UNS No. S42200	Bar/forging	540 (1004)
Seats	Austenitic nickel alloy ductile cast iron	ASTM A439, Type D-2	Bar	440 (825)
	Precipitation hardening	17-4PH	Bar	540 (1004)
Steam strainer screen	18 Cr-10 Ni	AISI 321		540 (1004)
Fasteners	Cr-Mo alloy steel (AISI 4140)	ASTM A193, Grade B7		400 (750)
	Carbon steel	ASTM A307, Grade B		400 (750)
	Cr-Mo-V steel	ASTM A193, Grade B16		482 (900)
	12 Cr steel	ASTM A437, Grade B4B		540 (1004)
	Inconel 718	Nickel chromium alloy UNS N07718		540 (1004)

[a] Normalized or normalized and tempered.

Bibliography

[1] API Standard 611, *General Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

[2] API Standard 613, *Special Purpose Gear Units for Petroleum, Chemical and Gas Industry Services*

[3] API Recommended Practice 684, *API Standard Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals, and Rotor Balancing*

[4] AMS-S-13165 [12], *Shot Peening of Metal Parts*

[5] ASME Performance Test Code (PTC) 6, *Steam Turbines*

[6] ASTM A515 [13], *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

[7] ASTM B127, *Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip*

[8] ASTM E1003, *Standard Practice for Hydrostatic Leak Testing*

[9] IEC 60953, *Rules for steam turbine thermal acceptance tests* (all parts)

[10] ISO 3448 [14], *Industrial liquid lubricants—ISO viscosity classification*

[11] ISO 10436, *Petroleum and natural gas industries—General-purpose steam turbines for refinery service*

[12] ISO 10494, *Gas turbines and gas turbine sets—Measurement of emitted airborne noise—Engineering/survey method*

[13] OSHA Form 174 [15], *Material Safety Data Sheet (MSDS)*

[12] SAE International (formerly the Society of Automotive Engineers), 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

[13] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

[14] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

[15] U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington, DC 20210, www.osha.gov.

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