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 supplier 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 supplier should identify any variations from this standard and provide details.

This standard requires the purchaser to specify certain details and features. A bullet (●) at the beginning of a subsection or paragraph indicates that either a decision by, or further information from, the purchaser is required. Further information should be shown on the datasheets (see example in Annex A) or stated in the quotation request and purchase order.

In this standard, U.S. customary (USC) units are included in parentheses 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 gas industry services. 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. Standards referenced in the text portion of the document are undated but refer to the specific editions referenced in this section.

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

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

ANSI [1] /API Standard 614, *Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries, Fifth Edition, April 2008 (Errata, May 2008)*

ANSI/API Standard 670, *Machine Protection Systems, Fourth Edition, December 2000*

ANSI/API Standard 671, *Special Purpose Couplings for Petroleum, Chemical and Gas Industry Services, Fourth Edition, August 2007*

API Recommended Practice 551, *Process Measurement*

API Recommended Practice 686, *Recommended Practice for Machinery Installation and Installation Design, Second Edition, December 2009*

API Recommended Practice 691, *Risk-based Machinery Management, First Edition, June 2017*

ANSI /AWS D1.1/D1.1M [2] , *Structural Welding Code—Steel*

ASME B1.1-2003 [3] , *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B1.3M-1986, *Screw Thread Gaging Systems for Dimensional Acceptability—Inch and Metric Screw Threads (UN, UNR, UNJ, M and MJ)*

ASME B1.13M-2005, *Metric Screw Threads: M Profile*

ASME B16.5-2009, *Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard*

ASME B16.47-2011, *Large Diameter Steel Flanges: NPS 26 through NPS 60 Metric/Inch Standard*

ASME B17.1 (R2008), *Keys and Keysets*

ASME B31.3-2010, *Process Piping*

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[1] American National Standards Institute, 1899 L Street, NW, 11th Floor, Washington, DC 20036, www.ansi.org.
[2] American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.
[3] American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990, www.asme.org.

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

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

ASME Boiler and Pressure Vessel Code: Section VIII: Pressure Vessels

ASME Performance Test Code (PTC) 6, Steam Turbines

ASTM A193/A193M [4] , *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

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

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

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

ASTM A395/A395M, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM A418/A418M, *Standard Practice for Ultrasonic Examination of Turbine and Generator Steel Rotor Forgings*

ASTM A437/437M-15, *Standard Specification for Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service*

ASTM A472/A472M, *Standard Specification for Heat Stability of Steam Turbine Shafts and Rotor Forgings*

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

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

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

ASTM D4304*(REV A 2006), Standard Specification for Mineral Lubricating Oil Used in Steam or Gas Turbines*

ASTM D5445-05, *Standard Practice for Pictorial Markings for Handling of Goods*

ASTM E94-(2010), *Standard Guide for Radiographic Examination*

ASTM E125, *Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings*

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

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E1417/E1417M, *Standard Practice for Liquid Penetrant Testing*

EN 1092-1 [5] , *Flanges and their joints—Circular flanges for pipes, valves, fittings and accessories, PN designated—Part 1: Steel flanges*

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[4] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

[5] European Committee for Standardization, Rue de la Science 23, B-1040 Brussels, Belgium, www.cen.eu.

IEC 60072 (all parts)[6] , *Dimensions and output series for rotating electrical machines*

IEC 60079 (all parts), *Explosive atmospheres*

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

IEC 60953 (all parts), *Rules for steam turbine thermal acceptance tests*

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

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

ISO 261:1998 [7] , *ISO general purpose metric screw threads—General plan*

ISO 3117, *Tangential keys and keyways*

ISO 3448:1992, *Industrial liquid lubricants—ISO viscosity classification*

ISO 3744:1994, *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 6708:1995, *Pipework components—Definition and selection of DN (nominal size)*

ISO 8068:2006, *Lubricants, industrial oils and related products (class L)—Family T (Turbines)— Specification for lubricating oils for turbines*

ISO 8501 (all parts), *Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness*

ISO 8821:1989, *Mechanical vibration—Balancing—Shaft and fitment key convention*

ISO 9606-1:2012, *Qualification testing of welders—Fusion welding—Part 1: Steels*

ISO 10721-2:1999, *Steel structures—Part 2: Fabrication and erection*

ISO 15607:2005, *Specification and qualification of welding procedures for metallic materials—General rules*

ISO 21940-32, *Mechanical vibration—Rotor balancing—Part 32: Shaft and fitment key convention*

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

NEMA 250:2014 [9] , *Enclosures for Electrical Equipment (1000 Volts Maximum)*

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

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[6] International Electrotechnical Commission, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iec.ch.

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

[8] Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, NE, Vienna, Virginia 22180, https://msshq.org.

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

[10] The Society for Protective Coatings, 800 Trumbull Drive, Pittsburgh, Pennsylvania 15205, www.sspc.org.

[11] NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

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

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

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

cf. hold down bolts (3.1.20)

3.1.4
approve
Provide written documentation confirming an agreement.

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

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

cf. mounting plate (3.1.38)

3.1.7
combined trip and throttle valve
A dedicated valve (separate from governor valve) that stops steam flow to the turbine in shutdown conditions and provides intermediate valve positioning for use during start-up or during abnormal conditions.

3.1.8
complex stiffness
The notation for the total equivalent stiffness and damping expression, including the cross-coupled terms as required for the hydrodynamic bearing or squeeze damper oil film.

3.1.9
control mechanism
All equipment between the speed governor and the governor-controlled valve(s) (such as linkages, pilot valves, and power servos).

3.1.10
critical speed
Shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.1.11
DN
diamétre nominal
Alphanumeric designation of size for components of a pipework system.

EXAMPLE DN20.

NOTE 1 Adapted from ISO 6708:1995.

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

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

3.1.12
design
Manufacturer's calculated parameter.

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

3.1.13
duplex
The provision of two microprocessors instead of one in situations where a fail-over function is required.

NOTE Availability of duplex system is typically in the 99 % range.

3.1.14
enclosure
Compartment designed to provide noise protection or weather protection, or both.

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

3.1.15
fail safe
System or component that will cause 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.

3.1.16
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.

3.1.17
gauge board
Bracket or plate used to support and display gauges, switches, and other instruments.

cf. panel (3.1.47)

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

3.1.18
general purpose application
Application that is usually spared or is in noncritical service.

3.1.19
governor-controlled valve
Device that controls the flow of steam into or out of the turbine in response to the speed governor.

3.1.20
hold down bolts
mounting bolts
Bolts holding the equipment to the mounting plate.

3.1.21
hydrodynamic bearings
Bearings that rely on the differential speed of the journal relative to the stator to pressurize a lubricating fluid in a wedge between the surfaces.

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

3.1.22
hysteresis or internal friction damping
Causes a phase difference between the stress and strain in any material under cyclic loading. This phase difference produces the characteristic hysteric loop on a stress-strain diagram and thus, a potentially destabilizing damping force.

3.1.23
idling adapter
(solo plate)
Device designed to rigidly hold in alignment the floating parts of certain types of couplings to allow uncoupled operation of the driving or driven machine without dismounting the coupling hub.

3.1.24
informative
For advice only.

cf. normative (3.1.43)

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

3.1.25
local
<Position of devices> on or near the equipment or console.

3.1.26
maximum allowable speed
Highest speed at which the manufacturer's design will permit continuous operation.

NOTE The maximum allowable speed of turbine is independent of the specified operating conditions and usually set by rotor stress values. See Figure 4 for the location of maximum allowable turbine speed in the overspeed testing range.

3.1.27
maximum allowable temperature
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) for handling the specified fluid (steam) at the specified maximum operating pressure.

NOTE Maximum allowable temperature in extraction steam turbine can depend on the extraction flow in addition to the specified maximum operating pressure.

3.1.28
maximum allowable working pressure
Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) for handling the specified fluid (steam) at the specified maximum operating temperature.

3.1.29
maximum continuous speed
Highest rotational speed (revolutions per minute) at which the turbine, as built and tested, is capable of continuous operation.

3.1.30
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 will be subjected to the maximum temperature and pressure under these conditions.

3.1.31
maximum exhaust pressure
Highest exhaust pressure at which the turbine is required to operate continuously.

NOTE The maximum exhaust pressure for steam turbines is determined by site steam conditions and is usually set by the purchaser.

3.1.32
maximum inlet pressure and temperature
Highest specified inlet steam pressure and temperature conditions, at the inlet to trip valve or at the inlet to combined trip and throttle valve, the turbine will be subject to.

3.1.33
maximum allowable momentary rotor overshoot speed
Maximum momentary speed determined by the manufacturer at which no damage will occur to the turbine rotor that will require immediate maintenance intervention.

3.1.34
maximum sealing pressure
Highest pressure the turbine seals are required to seal during any specified static or operating condition and during start-up and shutdown.

3.1.35
minimum allowable speed
Lowest speed (revolutions per minute) at which the manufacturer’s design will permit continuous operation.

3.1.36
minimum exhaust pressure
Lowest exhaust pressure at which the turbine is required to operate continuously.

3.1.37
minimum inlet steam pressure and temperature
Lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.1.38
mounting plate
Device used to attach equipment to concrete foundations or steel supports. This is either a baseplate(s), soleplates, or chockplates.

3.1.39
normal operating point
Point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the turbine vendor certifies the steam rate.

3.1.40
normal power
Turbine power at the normal operating point.

3.1.41
normal speed
Rotational speed (revolutions per minute) corresponding to the conditions of the normal operating point.

3.1.42
normally open
normally closed
<Manual hand valve> state during normal operation (see 7.7.2.5.3).

3.1.43
normative
Required.

cf. informative (3.1.24)

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

3.1.44
NPS
nominal pipe size
Value equal to a diameter in inches.

EXAMPLE NPS 3/4.

NOTE 1 Refer to ASME B31.3.

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

3.1.45
observed
A classification of inspection or test where the purchaser is notified of the schedule and the inspection or test is performed even if the purchaser or their representative is not present.

3.1.46
owner
Final recipient of the equipment who can delegate another agent as the purchaser of the equipment.

3.1.47
panel
Enclosure used to mount, display, and protect gauges, switches, and other instruments.

cf. gauge board (3.1.17)

3.1.48
PMI
positive material identification (PMI) testing
Any physical evaluation or test of a material to confirm that the material that has been or will be placed into service is consistent with the selected or specified alloy material designated by the owner/user. These evaluations or tests can provide either qualitative or quantitative information that is sufficient to verify the nominal alloy composition.

NOTE Adapted from API 578:2010.

3.1.49
PN
nominal pressure
Numerical designation relating to pressure that is a convenient round number for reference purposes.

EXAMPLE PN 100.

NOTE The permissible working pressure associated with a PN designation depends upon materials, design, and working temperature and has to be selected from the pressure/temperature rating tables in corresponding standards.

3.1.50
potential maximum power
Maximum power to which a steam turbine may be uprated at the specified normal speed and steam conditions if it is furnished with larger or additional nozzles and, possibly, with a larger governor-controlled valve or valves.

3.1.51
predicted momentary rotor overshoot speed
The speed that is expected to be achieved following an overspeed trip event.

3.1.52
pressure casing
Composite of all stationary pressure containing parts of the unit, including all nozzles, steam connections, and other attached parts.

3.1.53
purchaser
Agency that issues the order and specification to the vendor.

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

3.1.54
Ra
roughness magnitude
Arithmetic average of the absolute value of the profile height deviations recorded within the evaluation length and measured from the mean line.

NOTE 1 Adapted from ASME B46.1-2009 para 1-4.1.1.

NOTE 2 It is the average height of the entire surface, within the sampling length, from the mean line.

3.1.55
radially split
Split with the joint perpendicular to the shaft centerline.

3.1.56
rated power
Maximum specified steam turbine power output and its corresponding speed; it includes all the margin required by the specifications of the driven equipment.

3.1.57
rated speed
100 % speed
Highest rotational speed (revolutions per minute) required to meet any of the specified operating conditions.

NOTE Rated speed of steam turbine corresponds to its rated output power.

3.1.58
relief valve set pressure
Pressure at which a relief valve starts to lift.

3.1.59
remote
Location of a device if located away from the equipment or console, typically in a control room.

3.1.60
separation margin
Margin between a critical speed and the nearest required operating speed.

3.1.61
shutdown
Condition as determined by the equipment user that requires action to stop the equipment.

3.1.62
shutdown (HH) set point
Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.1.63
slow roll
Speed less than 5 % of the normal operating speed or the minimum speed permitted by design of components in the driver-driven train.

NOTE 1 Slow roll allows warm-up and initial check of equipment integrity prior to full speed operation.

NOTE 2 Slow roll speed in steam turbine driven centrifugal compressor train can be limited by design of dry gas seals.

3.1.64
soleplate
Plate attached to the foundation, with a mounting surface for equipment or for a baseplate.

3.1.65
spark resistant material
Material that is not prone to generate impact sparks under conditions of use.

NOTE Adapted from FM 7910 "Approval Standard for Spark Resistant Tools."

3.1.66
special-purpose application
Application for which the equipment is designed for uninterrupted, continuous operation in critical service, and for which there is usually no installed spare equipment.

NOTE Special-purpose steam turbine application is not limited by steam conditions, power, or turbine speed.

3.1.67
special tool
Tool that is not a commercially available catalog item.

3.1.68
stability analysis
The determination of the natural frequencies and the corresponding logarithmic decrements (log decs) of the damped rotor/support system using a complex eigenvalue analysis.

3.1.69
stage
Refers to an individual turbine blade row.

NOTE A turbine stage consists of one set of stationary and rotating blade rows.

3.1.70
support stiffness and damping
The equivalent oil film to ground complex stiffness characteristics. Pivot stiffness should be included in the oil film characteristics.

3.1.71
structure stiffness and damping
Refers to the bearing housing to ground equivalent complex stiffness.

3.1.72
synchronous tilt pad coefficients
Derived from the complex frequency dependent coefficients with the frequency equal to the rotational speed of the shaft.

3.1.73
steam rate
Quantity of steam required by the turbine per unit of power output measured at the output shaft of the turbine.

3.1.74
TIR
total indicator reading
total indicated runout
Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

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

3.1.75
TMR
triple modular redundancy
The provision of three microprocessors instead of one in situations where continuing functioning is required.

NOTE Availability of triple modular redundant system is typically in the 99.9 % range.

3.1.76
trip
Automated shutdown to ensure personnel safety (safety critical).

NOTE Shutdown such as turbine overspeed is considered a safety critical trip.

3.1.77
trip speed
<Turbine> speed at which the independent emergency overspeed device or shutdown system operates to shut down the steam turbine.

3.1.78
trip valve
A dedicated valve (separate from governor valve) that stops steam flow to the turbine in shutdown conditions (see 7.7.2.5.1).

3.1.79
ultimate load rating (hydrodynamic thrust bearing)
Load that will produce the minimum acceptable oil film thickness without inducing failure during continuous service, or the load that will not exceed the creep initiation or yield strength of the babbitt or bearing material.

3.1.80
unit responsibility
Obligation for coordinating the documentation, delivery, and technical aspects of all the equipment and all auxiliary systems included in the scope of the order.

3.1.81
vendor
Manufacturer or manufacturer's agent that supplies the equipment.

3.1.82
witnessed
A classification of inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or the purchaser's representative is in attendance.

3.2 Acronyms and Abbreviations

AF	amplification factor
cf.	(Latin conferre) confer or compare—cross-reference
ID	inner diameter
NDE	nondestructive examination
NPS	nominal pipe size
OD	outer diameter
PMI	positive material identification
PWHT	post-weld heat treatment
RTD	resistance temperature detector
SDS	safety datasheet
SI	the International System of Units (Système International d'Unités)
SPL	sound pressure level
USC	US customary

VDDR vendor drawing and data requirements

4 Unit Responsibility

If specified, the turbine vendor shall assume unit responsibility and shall ensure that all subvendors comply with the requirements of this standard and all reference documents.

NOTE The purchaser usually identifies the unit responsibility for machinery train. For generator drive application, the unit responsibility is generally assigned to the turbine vendor.

5 Requirements

5.1 Units of Measure

Purchaser's use of an SI datasheet indicates the SI (Système International d'Unités) system of measurements shall be used for all data, drawings, and maintenance dimensions. Purchaser's use of a USC datasheet indicates the US customary (USC) system of measurements shall be used.

NOTE 1 Informative steam turbine datasheets in SI units and USC units are provided in Annex A.1 and Annex A.2.

NOTE 2 Informative project design datasheets in SI units and USC units are provided in Annex A.3 and Annex A.4.

5.2 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.

5.3 Documentation Requirements

The hierarchy of documents shall be specified.

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

6 Basic Design

6.1 General

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

NOTE 1 It is realized that there are some services where this objective is easily attainable and others where it is difficult.

NOTE 2 Auxiliary system design and design of the process in which the equipment is installed are important in meeting this objective.

6.1.2 The vendor shall advise in the proposal if any components are designed for a finite life.

NOTE 1 It is recognized that these are design criteria.

NOTE 2 Annex B includes a guide to steam turbine nomenclature.

6.1.3 Only equipment that is field proven is acceptable. The purchaser shall specify the technology readiness level (TRL) from API 691 for qualified equipment.

NOTE Purchasers can use their engineering judgment in determining what equipment is field proven.

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

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

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

● **6.1.4** 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 conditions. The purchaser shall also specify the maximum and minimum values of the inlet, exhaust, and extraction/induction steam conditions.

6.1.4.1 The purchaser shall inform the vendor of any unusual process conditions that may cause the driven equipment to drive the turbine opposite its normal direction of rotation following a turbine trip (see 6.9.1.4).

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

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

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

NOTE Some steel flange standards do not state that flange ratings consider variations in pressure and temperature for short durations. In these situations, turbine flanges with higher rating can be needed.

6.1.5 Turbine 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; the purchaser may specify normal power or a selected percentage of rated power instead of rated power at these steam conditions to prevent oversizing or to obtain higher operating efficiency or both;

c) continuous operation at maximum continuous speed Nmc and at any other speed within the range specified;

d) continuous operation at rated power and speed with maximum inlet steam conditions and either 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 maximum inlet steam conditions (pressure and temperature), maximum exhaust steam pressure, and steam purity limits specified in Annex C (see 6.1.4.2 and 6.1.4.3);

h) operation uncoupled with maximum inlet steam conditions.

NOTE 1 Governing instability and high acceleration rates can occur during uncoupled operation and controlling action such as throttling of the inlet pressure can be needed.

NOTE 2 Operation of the turbine at no load (in any turbine section) and high speed or uncoupled usually needs reducing the inlet temperature to keep exhaust and/or extraction temperature within acceptable limits for the turbine, piping, and condenser (if applicable).

6.1.6 Turbine shall be designed for operation at speeds up to the trip speed without damage. This requirement shall not be construed to allow continuous operation above maximum continuous speed.

6.1.7 The turbine trip speed shall be 110 % of the maximum continuous speed (116 % of the rated speed).

6.1.8 For generator drive, the turbine trip speed shall be 10 % above the synchronous speed.

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

6.1.9.1 The equipment furnished by the vendor shall conform to the maximum allowable SPL specified.

6.1.9.2 The vendor shall provide expected values for maximum SPL per octave band for the equipment.

NOTE 1 The installed SPL depends on the installation.

NOTE 2 The SPL varies depending on the environment in which the source is located as well as the distance from the source.

6.1.10 Cooling water systems shall be designed on the water side based on the criteria in API 614.

6.1.10.1 The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. If such a conflict exists, the purchaser shall approve the final selection.

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

6.1.11 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor.

6.1.12 This arrangement shall provide the purchaser-defined adequate clearance areas and safe access for operation and maintenance.

6.1.13 Electrical Classification

6.1.13.1 Locations for installed equipment are classified as hazardous electrical areas or as unclassified. An unclassified area is considered nonhazardous; therefore, motors, electrical instrumentation, equipment, components, and electrical installations for unclassified areas are not governed by hazardous area electrical codes.

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

● **6.1.13.3** All applicable electrical codes shall be specified. Local electrical codes that apply shall be provided by the purchaser upon request.

NOTE The vendor can request from the purchaser any governmental requirements. The purchaser generally has other equipment at the site and is more familiar with the local governmental regulations.

6.1.14 Housings that enclose moving lubricated parts (bearings), shaft seals, highly polished parts, instruments, and control elements shall be designed for protection from moisture, dust, and other foreign matter during periods of operation and idleness.

NOTE Inert gas purge, seals and, or deflectors can be used for this purpose.

6.1.15 Major parts, such as casing components and bearing housings, shall be designed and manufactured with the use of shouldering dowels or keys to ensure accurate alignment on reassembly.

6.1.16 All components, which are specific as to rotational direction, top or bottom casing half location, or axial location in the casing, shall be designed to prevent incorrect installation.

6.1.17 The turbine and its accessories shall perform on the test stand(s) and on their permanent foundation within the acceptance criteria specified in 6.8.7.8. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

● **6.1.18** Many factors 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. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings. If specified, the vendor's representative shall witness the following:

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

b) the initial shaft alignment check at ambient conditions;

c) shaft alignment at operating temperature, i.e. hot alignment check.

NOTE Refer to API 686 for basic guidelines for conducting piping alignments, and shaft hot and cold alignments.

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

● **6.1.20** The equipment, including its auxiliaries, shall be suitable for operation, using the utility stream conditions specified.

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

NOTE Refer to O.3.4 in Annex O for parts lists and recommended spares.

6.1.22 Any maintenance item with a mass more than 25 kg (50 lb) shall be provided with lifting lugs or similar dedicated fixed lifting point(s).

6.1.22.1 Eyebolts are only acceptable for bearing housing covers and for internal components where other lifting arrangements are impractical.

6.1.22.2 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.

6.1.23 Bolting and Threads

● **6.1.23.1** The threading shall conform to ASME B1.1, ASME B1.13M, or ISO 261, as specified.

NOTE 1 ASME B1.13M and ISO 261 cover general metric screw threads, and ASME B1.1 covers general inch series screw threads.

NOTE 2 For the purposes of this provision, ISO 261 is equivalent to ASME B1.13M. Specific requirements for ISO 261 equivalence are found in 6.1.23.1.2.

NOTE 3 Glossary of terms for screw threads can be found in ASME B18.12–2001.

6.1.23.1.1 If ASME B1.1 threads have been specified, the thread series shall be variable pitch series UNC or UNRC, or constant pitch series 4, 6, or 8-UN or UNR and shall meet the following requirements.

a) Diameters shall be selected from Table 2 Column 1 of ASME B1.1. The threads shall be Class 2 for bolting, studs, and nuts.

b) For other threads and nuts, they shall be Class 2 or 3.

c) To prevent galling, if ASME B1.1 Class 3 external threads are used, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ASME B1.1 Class 3 tolerance for the outer diameter (OD) of the external thread and the inner diameter (ID) of the internal thread results in zero clearances. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads do not have any allowance, and therefore even if a Class 2 nut is used with a Class 3 external thread, metal-to-metal at maximum material conditions can develop.

6.1.23.1.2 If ISO 261 has been specified, the thread series shall be coarse or 3, 4, 6, or 8 pitch. Diameters shall be selected from Table 2, Column 1 of ISO 261 and shall meet the following requirements.

a) The threads shall be class 6g for bolting and studs, and class 6H for nuts.

b) For other threads, they shall be class 6g or 4h for external threads and class 6H or 5H for internal threads.

c) To prevent galling, if ISO class h/H position is specified for mating components, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ISO position h/H clearance for the OD of the external thread and the ID of the internal thread can result in zero clearance between the mating components. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads position G in the ISO system have an allowance, and therefore a nut using position G can be used with a position h external thread, and not develop metal-to-metal contact.

6.1.23.2 Gaging

6.1.23.2.1 Inspection or gaging requirements of threads shall be identified in accordance with ASME B1.1-1989 Section 6 "Screw Thread Designation."

6.1.23.2.2 All threaded products shall be visually inspected for gross defects. This visual inspection shall be made without magnification and is intended to detect gross defects such as missing or incomplete threads, defective thread profile, torn or ruptured surfaces, burrs and cracks.

6.1.23.2.3 Threads used to secure the positioning of components on turbine rotors shall be inspected in accordance with the following requirements.

a) Go, No-Go gaging shall be used if thread length is less than $1^1/_2$ times the gage length.

b) If thread length is greater than $1^1/_2$ times the gage length, they shall be checked in accordance with ASME B1.3M-1986 gaging system 22 using differential gaging.

c) The pitch diameter and cumulative variation of thread characteristics such as lead, flank angle, taper, and roundness (functional diameter) shall be measured and shall not exceed the tolerance on pitch diameter.

d) The major diameter of all external threads and minor diameter of all internal threads shall also be measured and shall not exceed the tolerances of the specification specified in 6.1.23.1.

6.1.23.3 Clearance shall be provided at all bolting locations to permit the use of respective socket or box wrench sizes.

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

NOTE For limited space locations, integrally flanged fasteners can be needed.

6.1.23.5 The bolting that needs to be disassembled for maintenance shall be as specified in 6.1.23.1.

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

6.2 Turbine Casings

6.2.1 The pressure casing(s) shall be designed to:

a) operate without leakage or internal contact between rotating and stationary components while subjected simultaneously to the maximum allowable working pressure (and corresponding temperature) and the worst-case combination of maximum allowable nozzle loads applied to all nozzles;

b) withstand the hydrostatic test;

c) operate at the most severe coincident pressure and temperature corresponding to the specified steam conditions.

6.2.1.1 The allowable tensile stress used in the design of the pressure casing (excluding bolting) for any material shall not exceed 25 % of the minimum ultimate tensile strength or 67 % of the minimum yield strength for that material at the maximum allowable temperature.

6.2.1.2 For cast materials, the allowable tensile stress shall be multiplied by the appropriate casting factor as shown in Table 1.

Table 1—Material Casting Factors

Type of NDE	Casting Factor
Visual, magnetic particle and/or liquid penetrant	0.8
Spot radiography	0.9
Ultrasonic	0.9
Full radiography	1.0

NOTE In general, deflection is the determining consideration in the design of casings. Ultimate tensile or yield strength is seldom the limiting factor.

6.2.1.3 A corrosion allowance of at least 3 mm (0.12 in.) shall be added to the casing thickness used in 6.2.1.1. This corrosion allowance also applies to the auxiliary connections exposed to the same steam as in the pressure containing casing. The vendor may propose alternative corrosion allowances if materials of construction with superior corrosion resistance are employed without affecting functionality, safety and reliability.

6.2.1.4 For casing joint bolting, the allowable tensile stress, as determined in 6.2.1.1 shall be used to determine the total bolting area based on hydrostatic load.

6.2.1.4.1 The preload stress shall not exceed 75 % of the bolting material minimum yield.

6.2.1.4.2 During hydro test, the bolting preload stress shall not exceed 90 % of the bolting material minimum yield. If the bolt preload exceeds 75 %, a positive method for measuring bolt elongation shall be used.

NOTE 1 Preloading the bolting is needed to prevent unloading the bolted joint due to cyclic (heating and cooling) operation.

NOTE 2 Thread stress in the nut or casing can be the limiting factor in the strength of the bolting.

NOTE 3 Torque wrenches are not an acceptable way to determine bolt elongation due to variations in friction factor.

6.2.1.5 The vendor shall state the source of the material properties used in 6.2.1.1, such as ASTM, ASME BPVC, etc., as well as the casting factors applied in the proposal.

6.2.1.6 Steam turbine pressure casings are outside of the scope of ASME BPVC. ASME BPVC manufacturing data report forms, and stamping are not required.

NOTE It is recognized that some other pressure vessel design codes do not exclude rotating equipment casings.

6.2.2 The vendor shall define the maximum allowable working pressure of the turbine casing and shall meet the requirements of 6.2.2.1 through 6.2.2.3.

6.2.2.1 The vendor shall define the physical limits and the maximum allowable working pressure of each part the turbine casing if it is designed as a split-pressure-level casing.

6.2.2.2 The exhaust casings of condensing turbines shall be capable of running at 150 °C (300 °F) or higher.

NOTE 1 During operation with poor vacuum or no-load testing, the exhaust temperature rises. This value is to ensure that the turbine can operate in either of these conditions.

NOTE 2 Some condensing turbines can need cooling of exhaust casing for this purpose.

6.2.2.3 For condensing turbines, the exhaust casings shall be designed for both full vacuum and for a maximum allowable working gauge pressure of at least 70 kPa (10 psi).

NOTE Refer to 7.2.2 for turbine relief valves.

6.2.3 Turbine casings 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 casings shall be discontinuous at the horizontal split to avoid a four-cornered joint.

6.2.4 The main joints of axially and radially split turbine casings shall use a metal-to-metal joint that is tightly maintained by bolting. Gaskets (including string type) shall not be used.

NOTE The main joint of turbine casing can incorporate a sealing compound that is suitable for the maximum specified operating conditions of steam.

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

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

NOTE This paragraph does not apply to thermal growth.

6.2.7 Supports, and the design of jackscrews and their attachments, shall be rigid enough to permit the turbine to be moved by the use of its lateral and axial jackscrews without permanent deformation of the support plates and jackscrews.

6.2.8 The use of threaded holes in pressure parts shall be minimized.

6.2.9 To prevent leakage in pressure sections of casings, metal equal to at least 12 mm (0.50 in.) in addition to any allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes.

6.2.10 Bolting shall be furnished as specified in 6.2.10.1 through 6.2.10.3.

6.2.10.1 Studs shall be supplied on the main joint of axially split casings and bolted end covers of radially split casings. Studs shall be used instead of cap screws, on all other joints, except where hexagonal head cap screws are essential for assembly purposes and have been approved by the purchaser.

6.2.10.2 The main casing joint studs and nuts shall be designed for the use of hydraulic bolt tensioning. Other methods of bolt tensioning may be used with purchaser's approval. Extent of special tooling provided by the vendor shall be agreed.

NOTE Thermal expansion of studs is another method for bolt tensioning. Torque wrenches are generally used where space does not allow use of thermal expansion or hydraulic bolt tensioning devices.

6.2.10.2.1 The vendor shall provide a schedule that detail the bolt torque or elongation requirements and tightening sequence for turbine main axial split joint, valve chest (if bolted to the casing) and exhaust casing.

NOTE Refer to ASME PCC-1 for torque tightening of ASME flanges.

6.2.10.2.2 Through bolting is preferred in areas of the turbine casing where temperature exceeds 410 °C (770 °F).

NOTE Through bolting is not possible in some areas of turbine such as steam chest.

6.2.10.3 As a minimum, the bolting for steel casings shall be high temperature alloy steel in accordance with ASTM A193 Grade B7 and carbon steel ASTM A194, Grade 2H nuts. Case hardened washers shall be provided to resist galling between the nuts and the spot faced (machined flat) surfaces on the casing. Where space is limited, ASTM A563, Grade A case hardened carbon steel nuts, as a minimum, shall be used.

6.2.11 Jackscrews, guide rods, cylindrical casing-alignment dowels and/or other appropriate devices shall be provided to facilitate disassembly and reassembly and shall meet the requirements of 6.2.11.1 through 6.2.11.3.

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

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

6.2.11.3 Lifting lugs or swivel eyebolts shall be provided for lifting the top half of the turbine casing.

6.2.12 Mounting surfaces on the turbine shall meet the following criteria.

a) They shall be machined to a finish of 6.3 μm (250 μin.) R_a or better.

b) Each mounting surface shall be machined within a flatness of 40 μm per linear meter (0.0005 in. per linear foot) of mounting surface.

c) They shall be in the same horizontal plane within 25 μm (0.001 in.) to prevent a soft foot.

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

e) The upper machined or spot faced surface shall be parallel to the mounting surface.

f) Hold down bolt holes shall be drilled perpendicular to the mounting surface or surfaces.

g) Holes shall be spot faced to a diameter suitable for a washer positioned eccentrically around the bolt.

h) Holes shall be 15 mm ($^1/_2$ in.) larger in diameter than the hold down bolt.

6.2.13 Turbine support feet shall be provided with vertical jackscrews and shall be drilled with pilot holes that are accessible for use in final doweling.

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

NOTE Slotted holes are used in some turbine designs to allow thermal expansion of casing.

6.3 Casing Appurtenances

6.3.1 Permanent connections with valves shall be provided to monitor turbine first stage pressure.

6.3.2 The exhaust casing on condensing turbine shall have inspection opening(s) for exhaust stage blade inspection. Machined and studded or flanged connections are required for inspection openings.

• **6.3.3** If specified, casing connections with valves shall be provided for an inert gas blanket to be used for preservation of turbine during storage at site before installation.

6.4 Pressure Casing Connections

6.4.1 All openings or nozzles for piping connections on pressure casings shall be at least nominal pipe size (NPS) 3/4 (DN 20).

6.4.2 Connections shall be in accordance with ISO 6708. Sizes DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225 (NPS 11/4, NPS 21/2, NPS 31/2, NPS 5, NPS 7, and NPS 9) shall not be used.

6.4.3 All connections shall be flanged or machined and studded, except where threaded connections are permitted by 6.4.6.

6.4.3.1 All connections shall be suitable for the maximum allowable working pressure(s) of its corresponding section. See 3.1.28 for definition of maximum allowable working pressure.

• **6.4.3.2** The purchaser shall specify the orientation of the main inlet and outlet steam connections.

6.4.3.3 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 welding-neck or socket-weld flange.

6.4.4 Connections welded to the casing shall meet the material requirements of the casing, including impact values and temperature pressure rating, rather than the requirements of the connected piping. All welding of connections shall be completed before the casing is hydrostatically tested.

6.4.5 Butt welded connections, size NPS $1^1/_2$ (DN 40) and smaller, shall be reinforced by using forged welding inserts or gussets. If gussets are provided, the piping shall be gusseted in two orthogonal planes to increase the rigidity of the piped connection, in accordance with the following criteria.

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

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

c) Gusset welding shall meet the fabrication requirements, including post-weld heat treatment (PWHT) if required, and the inspection requirements of this standard.

6.4.6 For connections other than main steam connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding NPS 11/2 (DN 40) may be used with purchaser's approval as follows:

a) on nonweldable materials;

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

6.4.7 The first segment of pipe nipples welded to the casing shall not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes NPS 1 (DN 25) and smaller and a minimum of Schedule 80 for NPS 11/2 (DN 40).

6.4.8 The nipple and flange materials shall meet the requirements of 6.4.3.

6.4.9 Flanges

6.4.9.1 Unless otherwise specified, the CLASS system applies, and all flanges shall conform to ASME B16.5 or ASME B16.47 Series B, as applicable.

NOTE 1 ISO 7005-1 describes flanges according to PN (EN1092–1) or CLASS (ASME B16.5 or ASME B16.47). PN flanges specify size by DN numbers, and CLASS flanges use NPS.

NOTE 2 ASME BPVC Section VIII, Division 2 "Design Rules for Flanged Joints" is typically used for the design of steam turbine inlet flanges with rating class designation 2500 and flange sizes greater than NPS 12 and for the design of exhaust end flanges of condensing steam turbines for the sizes that are not covered by ASME B16.5 or ASME B16.47 standards.

● **6.4.9.2** If the PN system is specified, all flanges shall conform to EN 1092-1, except as specified in 6.4.9.3 through 6.4.9.8.

NOTE EN 1092-1 flanges are PN 6, 10, 16, 25, 40, 63, 100, 160, 250, 320, and 400.

6.4.9.3 Steel flanges shall conform to the dimensional requirements of ASME B16.5 or ASME B16.47 Series B or EN 1092-1, as applicable.

● **6.4.9.4** If specified, ASME B16.47 Series A steel flanges shall be provided for class system flanges.

NOTE 1 ASME B16.47 covers flange diameters from NPS 26 through NPS 60.

NOTE 2 ASME B16.47 Series A flanges are thicker and heavier than Series B flanges in the same size and pressure rating.

6.4.9.5 The vendor shall provide pressure and temperature ratings for materials not covered by referenced flange standards.

6.4.9.6 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 the applicable ASME or EN standard are acceptable. Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing.

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

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

● **6.4.10** Machined and studded connections shall conform to the facing and drilling requirements of ASME B16.5 or ASME B16.47 or EN 1092-1, as specified. Studs and nuts shall be provided installed and the first 1.5 threads at both ends of each stud shall be removed.

NOTE Threads are removed at the end of the stud to allow the stud to bottom without damaging the end threads in the hole. Threads are removed from both ends of the stud to allow either end of the stud to be inserted into the threaded hole.

6.4.11 Machined and studded connections and flanges not in accordance with ASME B16.5, or ASME B16.47 or EN 1092-1 require purchaser's approval. The turbine vendor shall supply mating flanges, gaskets, studs, and nuts for these nonstandard connections.

6.4.12 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°. Pairs of studs or bolt holes shall straddle centerlines parallel to the main axes of the flange.

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

6.4.14 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 steam flow.

6.4.15 For socket-welded construction, there shall be a 1.5 mm ($^{1}/_{16}$ in.) gap between the pipe end and bottom of the socket before welding.

NOTE Refer to ASME B31.3 Figure 328.5.2B (3) and 328.5.2C.

6.4.16 Material Inspection of Pressure Casing

NOTE 1 Refer to 8.2.2 for inspection of nonpressure-containing parts.

NOTE 2 Refer to 3.1.52 for the definition of pressure casing.

6.4.16.1 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 if more stringent requirements are specified. Defects that exceed the limits imposed in 6.4.16.9 shall be removed to meet the quality standards cited, as determined by additional magnetic particle or liquid penetrant inspection as applicable before repair welding.

The vendor shall identify high stress areas of turbine steam chest and pressure casing that may be prone to creep damage and conduct nondestructive microstructure analysis (surface replication test or microscopy) of these areas after manufacturing to aid future remaining life assessment. A report of this analysis shall be furnished by the vendor to the purchaser.

● **6.4.16.2** 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 6.4.16.4. Alternative standards may be proposed by the vendor for approval by the purchaser.

NOTE Other national or local standards can be more stringent than ASME BPVC.

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

6.4.16.3 The purchaser shall be notified for their review and approval before the vendor makes a major repair to a pressure-containing part. Major repair, for the purpose of purchaser's notification, is any defect that equals or exceeds any of the three criteria defined below.

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

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

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

NOTE Major repairs typically occur at the foundry level in the manufacturing process. Purchaser's review and approval of major repairs to components depends on the criticality of the part, the material and heat treatment, and the extent of repair needed.

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

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

b) 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.

c) The inspection of 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.

6.4.16.5 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.

6.4.16.6 Cast and Nodular iron (if used for turbine diaphragms) shall be inspected only in accordance with magnetic particle and liquid penetrant methods.

6.4.16.7 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. If spot radiograph is required, as a minimum, one spot radiograph shall be performed for each welding procedure used and each welder used for pressure-containing welds.

6.4.16.8 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.

6.4.16.9 For cast steel magnetic casing parts examined by magnetic particle methods, acceptability of defects shall be based on a comparison with the photographs in ASTM E125. 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

6.5 External Forces and Moments

6.5.1 Turbines shall be designed to withstand external forces and moments at least equal to the values calculated in accordance with Annex D.

6.5.2 The turbine vendor shall tabulate the allowable forces and moments for each casing connection.

6.6 Rotating Elements

6.6.1 Shaft

6.6.1.1 The rotor shaft sensing areas to be observed by probes shall meet the requirements specified in API 670.

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

6.6.1.3 All shaft keyways shall have fillet radii conforming to ASME B17.1, ISO 3117, or other applicable national or international standard.

6.6.1.4 Keys shall be the same material as the shaft. Keys shall have chamfer at least equal to the adjacent keyway radii.

NOTE Keys for integrally forged rotors are sometimes made from material that is different from the shaft material.

6.6.1.5 Unless otherwise specified, integral flanged shaft end shall be provided. If an integral flange cannot be supplied, a keyless hydraulically fitted coupling hub shall be provided. Keyed coupling hub requires the purchaser's approval.

6.6.1.6 For mechanical drive application, the turbine vendor shall, jointly with the driven equipment vendor, establish the maximum transient torque value that may occur in the shafting system under start-up, and running conditions. All components, including couplings, and fit of coupling hub on shaft (if coupling hub is provided), shall be suitable for at least 115 % of this value.

For turbine driving a generator, a transient short circuit fault analysis shall determine that the generated stresses in the shafting shall not exceed its low cycle fatigue limit and in couplings, the torque shall not exceed the coupling vendor's peak torque rating (see 6.8.6.8).

6.6.1.7 Shaft shall not be plated or welded. Plating shall not be used to correct manufacturing errors.

6.6.1.8 Areas of shafts that are prone to damage by set-screws shall be relieved to facilitate the removal of components.

6.6.2 Rotor

6.6.2.1 The vendor shall provide a maximum allowable momentary rotor overshoot speed at which no damage would occur to the turbine rotor that would require immediate maintenance intervention.

6.6.2.1.1 The vendor shall identify the limiting component(s) at the maximum allowable momentary rotor overshoot speed.

6.6.2.1.2 The maximum allowable momentary rotor overshoot speed shall not be less than 127 % of rated speed at any specified condition for mechanical drives or 121 % of synchronous speed for generator drives.

6.6.2.1.3 The vendor shall provide the calculation of the predicted maximum momentary rotor overshoot speed following an overspeed trip event per Annex E to confirm that this speed shall not exceed the maximum allowable momentary rotor overshoot speed.

NOTE 1 Rubbing of internal seals and minor localized yielding of rotor components can occur and vibration levels can increase after an overspeed event.

NOTE 2 Local temperature, material properties, loads on the wheels, blades, blade roots, shrouds, shroud attachment methods, and other rotor elements are considered by turbine vendor when determining the maximum allowable momentary rotor overshoot speed.

NOTE 3 The vendor usually determines the predicted maximum momentary rotor overshoot speed and the maximum allowable momentary rotor overshoot speed after turbine rotor design is finalized.

NOTE 4 The purchaser and the vendor can agree on values other than those in 6.6.2.1.2 based on proven operating experience with some turbine rotors.

6.6.2.2 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).

6.6.2.2.1 Shafts of built-up rotors shall be machined from one-piece heat treated steel.

6.6.2.2.2 Shafts of built-up rotors with finished diameter 200 mm (8 in.) and larger shall be forged.

6.6.2.2.3 Shafts of built-up rotors with finished diameter less than 200 mm (8 in.) may be hot-rolled bar stock purchased to the same quality and heat treatment criteria as rotor forgings.

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

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

6.6.2.5 Rotors shall have steam deflector discs located between the bearing housings and outboard steam gland seal housings to prevent moisture from entering the bearing housings.

NOTE In some turbine designs, steam deflector discs are mounted inside casing end seal housings.

6.6.3 Blading

6.6.3.1 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 first and second upstream vane passing frequencies.

NOTE Blade natural frequencies are determined by blade shaker test, or finite element analysis method.

6.6.3.2 In the design analysis of blading, all potential sources of excitation and forces such as, but not limited to the following, shall be included:

a) first and second passing frequencies of upstream and downstream stationary blade rows;

b) steam passage splitters;

c) irregularities in vane pitch at horizontal casing flanges;

d) the first four turbine speed harmonics;

e) casing openings (exhaust or extraction);

f) partial arc diaphragms or nozzle plates;

g) internal struts and structural members in the inlet and exhaust casing or horizontal joints.

6.6.3.3 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.

6.6.3.4 Blade design shall meet one of the following requirements.

a) Resonance shall not occur within 10 % of the excitation frequencies mentioned in 6.6.3.1.

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 or Haigh or equivalent diagram) to check that the safety factor meets turbine vendor's design practices.

   2) Resonance is acceptable according to the standard design practices of the turbine vendor 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.

6.6.3.5 Prior to manufacturing, the vendor shall provide the following design data for each row of blades for the purchaser's review and acceptance:

a) steam bending stresses;

b) Campbell or equivalent diagrams;

c) Goodman or Haigh 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 mean and alternating blade stresses.

6.6.3.6 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.

6.6.3.7 Blade rows with shrouds retained by peened blade tenons shall meet the requirements of 6.6.3.7.1 through 6.6.3.7.3.

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

6.6.3.7.2 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.

6.6.3.7.3 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 requirements to ensure consistent results.

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

b) 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.

c) Peen the tenons to the shroud using the peening process 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.

d) Conduct the nondestructive examination (NDE) of the peened tenons to check for cracks.

NOTE API RP 687 includes considerations for peening of blade tenons.

6.6.3.8 The vendor shall identify to the purchaser all areas of shot peening in the blades and blade roots.

6.6.3.9 Shot peening shall conform to the requirements of 6.6.3.9.1 through 6.6.3.9.4.

6.6.3.9.1 X-ray defraction or other approved residual stress method test results shall be available to confirm the specified intensity results in the desired compressive depth required.

6.6.3.9.2 The setup shall be purged of all shot not used for the job peening. The peening set-up shall be qualified prior to peening the blades by installing Almen strips at the same angle and distance from the nozzles as the blades. The time, intensity, and shot size shall be the same as for the blades. The test Almen strip shall indicate the same intensity as required for the blading.

6.6.3.9.3 Shot shall not be larger than 50 % of the smallest radius on the surface to be peened.

6.6.3.9.4 Peen scan shall be applied to all blade areas to be peened. Inspect all blades with a black light after peening to confirm that all peen scan has been removed and there is full coverage of the required areas. Inspect with a 10X lighted magnification all fillets and radiuses after peening.

6.6.4 Speed-sensing Element

6.6.4.1 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.

6.6.4.2 The multi-toothed surface shall not be used as a gear for driving other mechanical components.

6.6.4.3 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.

6.7 Seals and Internal Stationary Components

6.7.1 Seals

6.7.1.1 Shaft seals or packing and inter-stage diaphragm seals shall be bronze, nickel bronze, stainless steel, or other suitable materials agreed by the purchaser and the turbine manufacturer. Gray cast iron and Ni-resist diaphragm seals are acceptable only with the purchaser's approval.

6.7.1.2 Casing end seals shall be replaceable labyrinth seals, brush seals, or a combination of both.

6.7.1.3 Interstage seals shall be replaceable labyrinths, brush seals, or a combination of both.

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

6.7.1.4.1 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.

6.7.1.4.2 The admission and the pressure of the sealing steam shall be automatically controlled with the normal operating sealing steam supply from a positive pressure section of the turbine.

6.7.1.5 A separate gland vacuum system shall be furnished to reduce external leakage from the casing end labyrinth seals and possible contamination of the bearing oil (see 7.5).

6.7.1.6 Unless otherwise specified, the vacuum system shall be supplied loose for mounting and connection by others.

NOTE Annex F shows typical gland sealing and leak-off systems.

6.7.1.7 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.

6.7.1.8 Sizing criteria for shaft seal and vacuum systems shall be agreed by the purchaser and turbine vendor if brush type shaft seals are used.

6.7.2 Internal Stationary Components

6.7.2.1 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.

6.7.2.2 All noncontrolled stage stationary blading shall be mounted in replaceable diaphragms or blade carriers.

6.7.2.2.1 Nozzles or blades shall be structurally welded (completely seal welded) to the diaphragm. Less than full perimeter welding, if proposed, shall require the purchaser's approval.

NOTE This is generally not applicable to blades in a reaction flow path.

6.7.2.2.2 Partial blading at the diaphragm split line shall be designed to prevent failure of the thin part of the blading during turbine operations.

6.7.2.3 All internal fasteners shall be positively retained or trapped to prevent them from entering the steam path.

NOTE Wire lock, slotted nuts, flanged washers, contoured threads, caulking strips and wedge lock washers are examples of devices typically used to retain fasteners inside steam turbines.

6.7.2.4 The arrangement of internal components in condensing turbine shall ensure that water cannot be trapped in the wet region (i.e. region operating at or below the onset of steam condensation).

6.7.2.4.1 The design of water drain holes in the wet region of a condensing turbine shall avoid these holes from becoming blocked by corrosion or debris.

6.7.2.4.2 In the case of drain holes in the diaphragms of an impulse type turbine, this shall be achieved by lining the drain holes with a corrosion-resistant material.

6.7.2.5 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.

6.7.2.5.1 The vendor shall indicate the required vertical and horizontal assembly clearances for each diaphragm or blade carrier.

6.7.2.5.2 In the condensing sections of reaction turbines, the diaphragms may be bolted to the exhaust casing.

6.7.2.6 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 to align packing holders during maintenance.

6.7.2.7 Turbines operating on saturated steam shall have components in the steam path (e.g. nozzles, blading, flow path of diaphragms) made of erosion-resistant materials or have appropriate erosion-resistant coatings applied. The type of erosion-resistant coating shall be agreed by the purchaser and the turbine vendor.

6.7.2.8 Provisions shall be made to minimize water cutting of wet stages (i.e. stages operating at or below the onset of steam condensation) at the diaphragm horizontal joint and the diaphragm to casing sealing face. Options to minimize the problem include stainless steel inlay or inserted rings.

NOTE Special provisions to minimize water cutting are often unnecessary for blade carriers of wet stages in reaction turbines, due to the higher sealing surface at horizontal split joint and low moisture content upstream of the blade carrier.

6.8 Dynamics

6.8.1 General

NOTE Refer to API RP 684 for more information on rotordynamics.

6.8.1.1 In the design of rotor-bearing systems, consideration shall be given to all potential sources of excitation and force such as, but not limited to, the following:

a) unbalance in the rotor system;

b) fluid forces from bearings, seals, and aerodynamics;

c) internal rubs;

d) blade and nozzle passing frequencies;

e) gear-tooth meshing and side bands;

f) coupling misalignment;

g) loose rotor-system components;

h) internal friction within the rotor assembly;

i) synchronous excitation from complimentary geared elements;

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

k) electrical line frequency.

NOTE 1 The frequency of a potential source of excitation or force can be less than, equal to, or greater than the rotational speed of the rotor.

NOTE 2 When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor-bearing support system coincides with a natural frequency of that system, it is in a state of resonance.

NOTE 3 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, is related to the amount of damping in the system.

6.8.1.2 Resonances of structural support systems that are within the vendor's scope and that affect the rotor vibration amplitude shall not occur within the required operating speed range or the specified separation margins (SM_r) (see 6.8.2.9). The dynamic characteristics of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing-support system [see 6.8.2.3, Item e)].

6.8.1.3 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 a Campbell diagram, submitted to the purchaser for review and included in the instruction manual [see Annex G for vendor drawing and data requirements (VDDR)].

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

6.8.1.4 Lateral analysis requirements specified in 6.8.2, 6.8.4, and 6.8.5 shall be reported per 6.8.1.4.1 through 6.8.1.4.3 and Annex H.

6.8.1.4.1 The basic rotordynamic report shall be provided for purchaser's review and approval.

● **6.8.1.4.2** If specified, the reporting requirements identified as required for independent audit of the results shall be provided.

● **6.8.1.4.3** If specified, provisions shall be made to provide the purchaser with access to drawings to develop independent models of the rotor, bearings, and seals. These data shall be made available in electronic format.

6.8.1.5 Torsional analysis requirements specified in 6.8.6 shall conform to 6.8.1.5.1 through 6.8.1.5.3 and Annex I.

6.8.1.5.1 The basic torsional report for all covered machines shall be provided for purchaser's review and approval.

● **6.8.1.5.2** If specified, the reporting requirements identified as required for independent audit of the results shall be provided.

- **6.8.1.5.3** If specified, provisions shall be made to provide the purchaser with access to drawings to develop independent models of the rotor, bearings, and seals. These data shall be made available in electronic format.

6.8.2 Lateral Analysis

6.8.2.1 Critical speeds and their associated AFs shall be determined by means of a damped unbalanced rotor response analysis.

6.8.2.2 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 the stiffness range to produce free-free to rigid support modes.

6.8.2.3 The lateral analysis shall include, but not be limited to, the following:

a) rotor stiffness, mass, and polar and transverse moments of inertia, including coupling halves, and rotor stiffness changes due to shrunk on components and temperature variation along the rotor;

b) material properties as a function of operating temperature variation along the turbine shaft;

c) bearing lubricant-film stiffness and damping values, including changes due to speed, load, minimum to maximum preload, range of oil inlet temperature and pressure, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetric loading that may be caused by partial arc steam admission, bearing support effects, thermal effects on the bearings, and eccentric clearances;

NOTE Minimum and maximum bearing clearance for a tilt pad bearing occurs at the maximum and minimum preload conditions respectively. These can be calculated using the following formulas.

For minimum clearance at maximum preload:

$$\text{Preload}_{max} = 1 - \frac{\text{Bearing radius}_{min} - \text{Shaft radius}_{max}}{\text{Pad bore}_{max} - \text{Shaft radius}_{max}}$$

$$\text{Bearing clearance}_{min} = \text{Bearing radius}_{min} - \text{Shaft radius}_{max}$$

For maximum clearance at minimum preload:

$$\text{Preload}_{min} = 1 - \frac{\text{Bearing radius}_{max} - \text{Shaft radius}_{min}}{\text{Pad bore}_{min} - \text{Shaft radius}_{min}}$$

$$\text{Bearing clearance}_{max} = \text{Bearing radius}_{max} - \text{Shaft radius}_{min}$$

d) for tilt-pad bearings, the pad pivot stiffness and pad inertia;

e) support structure stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range; for machines whose dynamic support stiffness values are less than or equal to 3.5 times the maximum bearing stiffness values at 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 structure characteristic values used in the analysis and the basis for these values (for example, modal tests of similar rotor structure systems or calculated structure stiffness values);

f) rotational speed, including the various starting-speed detents, operating speed, and load ranges (including agreed test conditions if different from those specified), trip speed, and coast-down conditions;

g) the influence over the operating range of the casing end gland seals; minimum and maximum stiffness shall be considered taking into account the tolerance on the component clearance;

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

i) the effective stiffness diameter at the turbine wheel stages;

j) for tilt-pad squeeze film damper bearings, damper mass, stiffness and damping values considering the component clearance and centering tolerance, oil inlet temperature range, and operating eccentricity.

NOTE Details and product of the analysis are covered in 6.8.2.7 and 6.8.2.8.

● **6.8.2.4** If specified, the vendor with unit responsibility shall provide a train lateral analysis for machinery trains with flexible couplings.

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

6.8.2.6 A separate damped unbalanced response analysis shall be conducted within the speed range of 0 % to 150 % of N_{mc}. Unbalance shall analytically be placed at the locations defined in Figure 1 and shall meet the requirements of 6.8.2.6.1 through 6.8.2.6.3.

6.8.2.6.1 For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads.

6.8.2.6.2 For conical (asymmetric) modes, unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing.

6.8.2.6.3 For overhung modes, the unbalances shall be based on the overhung mass.

6.8.2.7 Figure 1 shows 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 (1).

In SI units:

$$U_r = 6350 \frac{W}{N_{mc}} \left(for\ N_{mc} < 25{,}000\ rpm\right) \tag{1a}$$

$$U_r = \frac{W}{3.937} \left(for\ N_{mc} \geq 25{,}000\ rpm\right)$$

In USC units:

$$U_r = 4 \frac{W}{N_{mc}} \left(for\ N_{mc} < 25{,}000\ rpm\right) \tag{1b}$$

$$U_r = \frac{W}{6250} \left(for\ N_{mc} \geq 25{,}000\ rpm\right)$$

where

U_a	= 2 × U_r = input unbalance for the unbalance response analysis, g-mm (oz-in.);
U_r	is the maximum allowable residual unbalance, g-mm (oz-in.);
N_{mc}	is the maximum continuous operating speed, rpm;
W	is the journal static load in kg (lbm), 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 (lbm) (see Figure 1).

NOTE Above 25,000 rpm, the limit is based on 0.254 µm (10 µin.) mass displacement, which is in general agreement with the capabilities of conventional balance machines and is invoked for small rotors running at high speeds.

For coupling unbalance placement (unbalance based on the coupling half weight), the unbalance shall be 2 times the maximum of the following assembly check balance values, calculated by Equation (2) and Equation (3).

$$U_{ac1} = \frac{K_1 \times W}{N_{mc}} \tag{2}$$

$$U_{ac2} = K_2 \times W \tag{3}$$

where

K_1	63,500 (40);
K_2	12.7 (0.008);
U_{ac}	is the coupling unbalance used in the response analysis, g-mm (oz-in.);
N_{mc}	is the maximum continuous operating speed, rpm;
W	is the half coupling mass, kg (lbm) (see Figure 1).

6.8.2.8 Additional analyses shall be made for use with the verification test specified in 6.8.3. The location of the unbalance shall be determined by the vendor.

6.8.2.8.1 The unbalance shall not be less than 2 times or greater than 8 times the value from Equation (1) or as specified in 6.8.2.8.2. Any test stand parameters that influence the results of the analysis shall be included.

6.8.2.8.2 For coupling unbalance placement (unbalance based on the coupling half weight), the unbalance shall not be less than 2 times or greater than 8 times the maximum value of Equations (2) and (3).

NOTE For most machines, there is only one plane readily accessible for the placement of an unbalance, for example, the coupling flange on a single ended drive machine. However, some turbomachinery (steam turbines) can provide additional externally accessible balance planes.

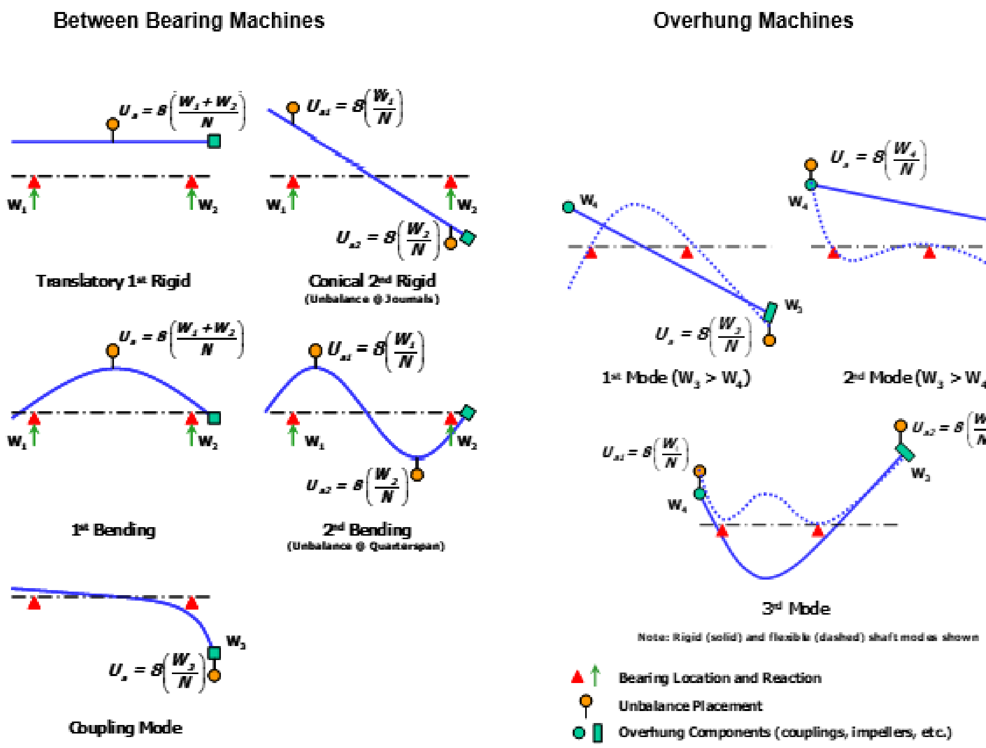


Figure 1—Unbalance Placement

6.8.2.9 The damped unbalance response analysis shall indicate that the machine meets the requirement given by Equation (4).

$$SM_a = SM_r \tag{4}$$

where

SM_r is the required separation margin, %;

SM_a is defined in Figure 2.

a) If the AF at a particular critical speed is less than 2.5, the response is considered critically damped and separation margin is not required ($SM_r - 0$).

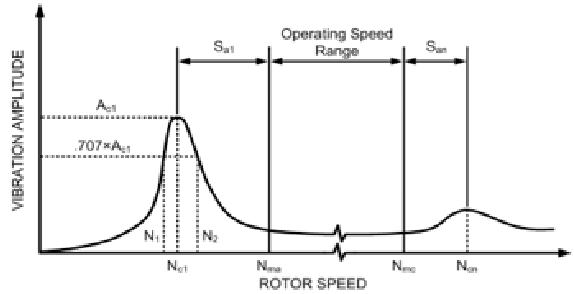
b) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is below the minimum allowable speed N_{ma}, the SM_r is given by Equation (5).

$$SM_r = 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{5}$$

c) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is above the maximum continuous speed N_{mc}, the SM_r is given by Equation (6).

$$SM_r = 10 + 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{6}$$

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



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 × A_{c1}
N_2 = Final (greater) speed at 0.707 × 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 × S_{a1} / N_{ma}
SM_{an} = Actual separation margin of n^{th} critical speed (%)
= 100 × 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 2—Rotor Response Plot

6.8.2.10 The calculated unbalanced peak-to-peak response at each vibration probe, for each unbalance amount and case as specified in 6.8.2.7, shall not exceed the mechanical test vibration limit, A_{vl}, of [25.4 μm (1.0 mil) or Equation (7), whichever is less] over the range of N_{ma} to N_{mc} as shown in Figure 3.

In SI units:

$$A_{vl} = 25.4\sqrt{\frac{12,000}{N_{mc}}} \tag{7a}$$

In USC units:

$$A_{vl} = \sqrt{\frac{12,000}{N_{mc}}} \tag{7b}$$

where

A_{vl} is the mechanical test vibration limit, μm (mil);

N_{mc} is the maximum continuous speed, rpm.

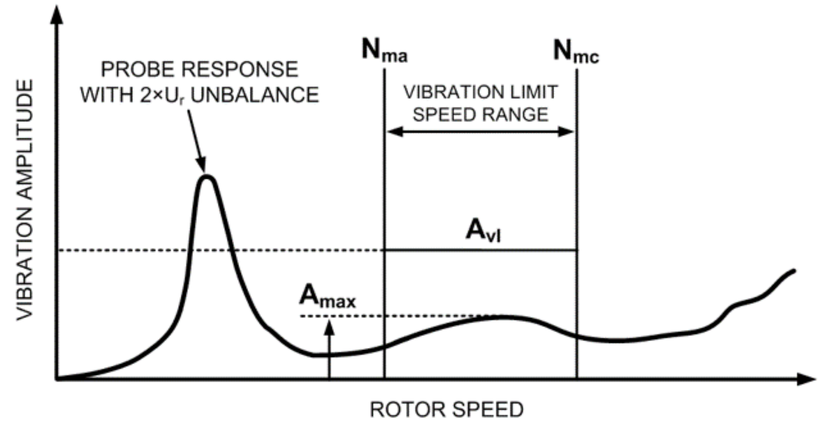


Figure 3—Plot of Applicable Speed Range of Vibration Limit

6.8.2.11 For each unbalance amount and case as specified in 6.8.2.7, the calculated major-axis, peak-to-peak response amplitudes at each close clearance location shall be multiplied by a scale factor defined by Equation (8).

$$S_{cc} = A_{vl}/A_{max} or\, 6, whichever\, is\, less \quad (8)$$

where

S_{cc}	is the scale factor for close clearance check;
A_{vl}	is the mechanical test vibration limit defined in 6.8.2.10;
A_{max}	is the maximum probe response amplitude (p-p) considering all vibration probes, over the range of N_{ma} toN_{mc}, for the unbalance amount/case being considered.

NOTE The scale factor will be greater than or equal to one, to meet the requirements of 6.8.2.10.

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. Consideration shall be given to:

a) centrifugal/thermal growth;

b) bearing lift;

c) rotor sag;

d) nonconcentricity (of stator to the bearings).

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

6.8.2.12 If the analysis indicates that if either of the following requirements cannot be met:

a) the required separation margins, or

b) the requirements of 6.8.2.10 or 6.8.2.11,

and the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes, separation margins, and AFs shall be agreed by the purchaser and the vendor.

6.8.3 Unbalanced Rotor Response Verification Test

6.8.3.1 An unbalanced rotor response test shall be performed as part of the mechanical running test (see Section 8), 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 and bearing loads as was used in the analysis specified in

6.8.2.8 shall be used for determining the validity of the damped unbalanced response analysis. To accomplish this, the requirements of 6.8.3.1.1 through 6.8.3.1.6 shall be followed.

NOTE API 684 contains discussions related to verification testing performed in a balancing bunker.

6.8.3.1.1 During the mechanical running test, the amplitudes and phase angle of the shaft vibration from trip to slow roll speed shall be recorded before and after the 4-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 a coastdown, with convenient increments of speed; typically, 50 rpm. Any vibration amplitude and phase detected is usually the result of residual unbalance and mechanical and electrical runout.

6.8.3.1.2 The unbalance that was used in the analysis performed in 6.8.2.8 shall be added to the rotor in the location used in the analysis.

6.8.3.1.3 The machine shall then be brought up to trip speed after being held at maximum continuous speed until bearing temperatures and radial vibrations have stabilized, and the indicated vibration amplitudes and phase shall be recorded during the coastdown using the same procedure as 6.8.3.1.1.

NOTE Temperature and vibration stabilization can be assumed if respective changes are less than 1 °C (2 °F) and ± 20 % of vibration limit over 15 minutes at constant oil inlet conditions.

6.8.3.1.4 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 lateral damped analysis report.

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

6.8.3.1.5 The corresponding indicated vibration data taken in accordance with 6.8.3.1.1 and 6.8.3.1.4 shall be vectorially subtracted. Slow roll runout shall be checked prior to subtraction.

NOTE Slow roll runout data taken prior to subtraction is expected to be nearly identical for both runs.

6.8.3.1.6 The results of the mechanical run including the unbalance response verification test shall be compared with those from the analytical model specified at 6.8.2.8. The probe orientation used in the analysis shall be the same as on the machine for the comparison to be valid.

● **6.8.3.2** If specified, the unbalance verification test shall be performed in an operation speed balance bunker. Placement of the unbalance weight and vibration readings shall be agreed.

6.8.3.3 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(s) determined on test shall not deviate from the corresponding critical speed ranges predicted by analysis by more than ± 5 %.

b) At N_{mc}, the probe responses from the results of 6.8.3.1.5 shall not exceed the predicted range.

6.8.3.4 The vendor shall determine whether the comparison made is for absolute or relative motion.

NOTE For absolute motion, bearing housing vibration is vectorially added to relative probe readings.

6.8.3.5 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.

6.8.3.6 After correcting the model, if required, the response shall be checked against the limits specified in 6.8.2.9 through 6.8.2.11. The vendor shall explain how the model was corrected.

6.8.4 Stability Analysis

6.8.4.1 A stability analysis shall be performed on all turbine rotors whose N_{mc} is greater than the first undamped critical speed on rigid supports (FCSR) in accordance with 6.8.2.3. The stability analysis shall be performed at API defined N_{mc}.

6.8.4.2 The model used in the stability analysis shall include the items listed in 6.8.2.3 to produce the minimum log decrement.

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

6.8.4.4 For turbine rotors that have quantifiable external radial loading (including partial admission steam forces), the stability analysis shall also include the external loads associated with the dimensional and operating conditions defined in 6.8.4.5. For some rotors, the unloaded (or minimal load condition) may represent the worst stability case and shall be considered.

6.8.4.5 The anticipated cross coupling, QA, present in the rotor is defined by Equation (9).

For axial flow turbine rotors:

$$q_a = \frac{(HP)B_t C}{D_t H_t N_r} \tag{9}$$

where

HP	is the rated power per turbine stage, Nm/s (HP);
B_t	is 1.5;
C	is 9.55 (63);
D_t	is the stage blade pitch diameter, mm (in.);
H_t	is the effective stage blade height, mm (in.);
N_r	is the normal operating speed for calculation of aerodynamic excitation, rpm;
q_a	is the cross coupling of stage.

Equation (9) is calculated for each stage of the rotor. QA is equal to the sum of q_a for all stages.

6.8.4.6 All potential sources of excitation shall be included in the stability analysis. These shall include, but not be limited to, the following:

a) labyrinth seals;

b) blade flow aerodynamic effects;

c) internal friction.

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

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

6.8.4.7 The stability analysis shall be calculated atN_{mc}.

6.8.4.8 The steam conditions defined for the normal operating point shall be extrapolated to N_{mc} within the operating map if the steam conditions at N_{mc} are different from that at the normal operating point.

6.8.4.9 The dynamic coefficients of the labyrinth seals shall be calculated at the minimum and maximum expected seal operating clearance.

6.8.4.10 The frequency and log decrement of the first forward damped mode shall be calculated progressively for the following configurations:

a) rotor and support system only;

b) each source from 6.8.4.6 used in the analysis;

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

6.8.4.11 A sensitivity analysis shall be performed with a varying amount of cross coupling introduced at the rotor mid-span.

6.8.4.11.1 The applied cross coupling shall extend from zero to that required to produce a zero log decrement.

6.8.4.11.2 The anticipated cross coupling QA shall be plotted.

6.8.5 Stability Acceptance Criteria

6.8.5.1 The stability analysis shall indicate that the machine, as calculated in 6.8.4.1 through 6.8.4.11, shall have a final log decrement, δ_f greater than 0.1.

● **6.8.5.2** If after all practical design efforts have been exhausted to achieve the requirements of 6.8.4.9, acceptable levels of the log decrement, δ_f shall be agreed, or if specified, a stability test to measure damping ratio and to determine the corresponding log decrement, shall be performed as specified by the purchaser.

6.8.6 Torsional Analysis

6.8.6.1 For trains including gears, 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 6.8.6.3 through 6.8.6.7.

● **6.8.6.2** If specified, for direct driven steam turbine trains, the turbine vendor shall perform a torsional vibration analysis of the complete coupled train and shall be responsible for directing any modifications necessary to meet the requirements of 6.8.6.3 through 6.8.6.7.

A simplified torsional model (lumped rotor inertia and stiffness) is sufficient for direct driven steam turbine trains.

NOTE The intent of the simplified analysis is to calculate the primary (coupling) modes of the system. Primary modes are those influenced predominantly by the coupling torsional stiffness.

6.8.6.3 The torsional analysis shall include, but not be limited to, the following:

a) torsional stiffness and inertia of built-up shafts;

b) effects of operating temperature on material properties;

c) calculation and distribution of polar mass moment of inertia;

d) nonlinear effects from sources such as elastomeric or torque limiting couplings;

e) coupling torsional stiffness boundary;

f) electromechanical stiffness and damping in generator air gap;

g) penetration factor effects on torsional stiffness due to:

1) shaft diameter changes;

2) keyways;

3) shrink fits;

4) bolted assemblies;

h) damping from the following sources:

1) material and frictional damping within assemblies;

2) fluid/viscous devices (if applicable).

6.8.6.4 Excitation of torsional natural frequencies shall be considered in the analysis. These sources shall include, but are not limited to, the following:

a) torsional excitation resulting from electric generators;

b) one and two times electrical line frequency (applicable to electric generator drive);

c) one and two times operating speed(s).

6.8.6.5 The primary (coupling) modes shall be at least 10 % above or 10 % below the 1X electrical excitation frequency.

6.8.6.6 The intersection of the primary (coupling) modes with the 1X mechanical excitation shall be at least 10 % above or 10 % below the specified operating speed range from minimum to N_{mc}.

6.8.6.7 The intersection of all other torsional natural frequencies with any possible excitation frequency shall be at least 10 % above or 10 % below the specified operating speed range from minimum to N_{mc}.

6.8.6.7.1 If torsional resonances are calculated to fall within the margin specified in 6.8.6.7 (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.

6.8.6.7.2 The analysis shall show that all shaft sections and couplings have infinite life using an agreed criterion.

● **6.8.6.8** If specified, for turbine trains including an electrical generator, a transient short circuit fault analysis shall be performed in accordance with 6.8.6.8.1 and 6.8.6.8.2.

6.8.6.8.1 The following faults shall be considered, but not be limited to:

a) short circuits:

1) line-to-line;

2) two-phase;

3) three-phase;

4) line-to-ground;

5) line-to-line-to-ground;

b) synchronization (generators):

1) single-phase;

2) three-phase.

6.8.6.8.2 For these fault conditions, generated stresses in the shafting shall not exceed the low cycle fatigue limit and in couplings, the torque shall not exceed the coupling vendor's peak torque rating.

NOTE The analysis for these fault conditions assumes a onetime event. It is possible that some components identified by the analysis need replacement following the fault event.

● **6.8.6.9** If specified, alternating torques produced by breaker reclosure shall be shown to have no negative impact on the intended operating life of the equipment train.

6.8.7 Vibration and Balancing

6.8.7.1 Major parts of the rotating element such as shaft, discs, and balance drum (if provided) shall be individually dynamically balanced before assembly, to Equation (1) or better.

6.8.7.1.1 If 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 21940-32.

6.8.7.1.2 Keyways 180° apart, but not in the same transverse plane, shall also be filled.

6.8.7.1.3 The initial balance correction to the bare shaft shall be recorded.

6.8.7.1.4 The components mounted on the shaft shall also be balanced in accordance with the "half-key-convention," as described in ISO 8821.

6.8.7.2 The rotating element shall be sequentially multiplane dynamically balanced during assembly unless an operating speed balance is to be performed. This shall be accomplished after the addition of no more than two major components. 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. The maximum allowable residual unbalance per plane (journal) shall be calculated as per Equation (1) as applicable.

6.8.7.2.1 In the sequential balancing process, any half keys used in the balancing of the bare shaft (see 6.8.7.1) 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.

6.8.7.2.2 The weight of all half-keys used during final balancing of the assembled element shall be recorded on the Residual Unbalance Worksheet (see Annex J for sample filled-in worksheets).

● **6.8.7.3** If specified, completely assembled rotating elements shall be subject to operating speed balancing.

6.8.7.4 High-speed Balancing Procedure

6.8.7.4.1 The following information shall be provided, prior to high-speed balancing:

a) the contract rotor dynamic analysis;

b) final low speed balance records when applicable;

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

d) job and balance stand bearing details.

6.8.7.4.2 The rotor shall be supported in bearings of the same type and with similar dynamic characteristics as those in which it will be supported in service.

NOTE 1 Job bearings can be used if practical.

NOTE 2 High-speed balance units run under a vacuum. Operation in a vacuum can need temporary end seals for evacuated bearings.

6.8.7.4.3 The rotor shall be completely assembled including thrust collars with locking collars and any auxiliary equipment. Shaft end seals are not added.

6.8.7.4.4 The high-speed drive assembly shall be shown to have an effect less than 25 % of the balance tolerance.

NOTE In some cases, the facility drive coupling and adapter can be adequate to simulate the job-coupling half moment. Occasionally, the job-coupling hub with moment simulator can be needed, especially for the outboard ends of double-end drive steam turbines.

● **6.8.7.4.5** If specified, two orthogonally located radial non-contacting vibration probes shall be mounted next to the bearings, at mid-shaft or at overhung locations as agreed by purchaser and vendor.

6.8.7.4.6 If non-contacting 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 machine when nonstandard mounting is used (i.e. cantilevered probe holders).

6.8.7.4.7 The smallest pedestal rated for the rotor weight shall be used without pedestal stiffening engaged.

NOTE A reduction of the rotor balance criteria can be needed for light rotors used with larger pedestals.

6.8.7.4.8 Prior to high speed balance, the complete rotor shall be low speed balance checked in the high speed balance facility. If the measured unbalance exceeds five times the maximum allowable residual unbalance for the rotor, then the cause of the unbalance shall be identified prior to high speed balancing.

NOTE The purpose of identifying the unbalance is to increase the possibility of the rotor successfully traversing its critical speed(s) and the likelihood of a successful balance.

6.8.7.4.9 Prior to balancing, the rotor residual unbalance shall be stabilized. This shall be accomplished by:

a) record low speed residual unbalance (amount and phase) before running up in speed;

b) run rotor to maximum continuous speed N_{mc}, hold for 3 minutes and take a reading;

c) run rotor to trip speed plus 4 % of N_{mc}, hold for 3 minutes;

d) reduce to maximum continuous operating speed and record vibration readings for each pedestal;

e) reduce speed and record low speed unbalance again;

f) repeat until readings taken in 6.8.7.4.9 days) and 6.8.7.4.9 e) are within 25 % of the vibration requirement for Item d) and 25 % of the balance requirement in 6.8.2.6 for Item e).

6.8.7.4.10 Field accessible balance holes shall not be used for balance corrections.

6.8.7.4.11 Balance weights (if used) shall be compatible with disk material and suitable for the operating environment.

6.8.7.4.12 After the rotor is balanced within the tolerances of 6.8.7.5, repeat the final balance run with the pedestal stiffening engaged.

6.8.7.4.13 Upon completion of the balancing, Bode and polar plots for each pedestal velocity and non-contacting probe (if used) shall be provided for the initial run, stabilized rotor prior to balancing, and final balanced rotor with and without pedestal stiffening. Non-contacting probe data shall be compensated for slow roll mechanical and electrical runout.

6.8.7.5 The acceptance criteria and balance speeds shall be agreed between the purchaser and vendor.

If non-contacting vibration probes have been specified in 6.8.7.4.5, the acceptance criteria for the readings shall be agreed.

NOTE The acceptance criteria are typically based on the high-speed balance provider's experience and can be expressed in pedestal vibration, pedestal force or residual unbalance.

6.8.7.6 A rotor that has been high-speed balanced shall have its unbalance recorded. No corrections shall be made to the rotor. A permanent mark or part (such as a keyway) shall be used and recorded for the phase reference.

NOTE 1 This procedure is for future reference if a low speed balance check is performed on the rotor before installation.

NOTE 2 A high-speed balanced rotor generally does not meet the low speed balance criteria.

6.8.7.7 For a rotor that has been low-speed balanced, a low speed residual unbalance check shall be performed in a low-speed balance machine and recorded in accordance with the Residual Unbalance Worksheet (see Annex J for sample filled-in worksheets).

6.8.7.8 During the mechanical running test of the machine, assembled with the balanced rotor, operating at any speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the value from Equation (10).

In SI units:

$$A_{vl} = \left[25.4\sqrt{\frac{12,000}{N_{mc}}}\ or\ 25.4\right] \text{whichever is less} \tag{10a}$$

In USC units:

$$A_{vl} = \left[\sqrt{\frac{12,000}{N_{mc}}}\ or\ 1.0\right] \text{whichever is less} \tag{10b}$$

where

A_{vl} is the mechanical test vibration limit, µm (mil);

N_{mc} is the maximum continuous speed, rpm.

At any speed greater than the maximum continuous speed N_{mc} up to and including the trip speed of the driver, the vibration level shall not increase more than 12.7 µm (0.5 mil) above the value recorded by each probe at the N_{mc} prior to accelerating the rotor to trip.

NOTE These limits are not to be confused with the limits specified in 6.8.3 for shop verification of unbalanced response.

6.8.7.9 Electrical and mechanical runout shall be determined by rotating the rotor through the full 360° supported in V blocks at the journal centers. The combined runout, measured with a non-contacting vibration probe, and the mechanical runout, measured with dial indicators at the centerline of each probe location, shall be continuously recorded during the rotation. Teflon shall not be used in the V blocks.

NOTE The rotor runout determined above is generally not reproduced when the rotor is installed in a machine with hydrodynamic bearings. This is due to pad orientation on tilt pad bearings and effect of lubrication in all journal bearings.

6.8.7.10 Records of electrical and mechanical runout for the full 360° at each probe location shall be included in the mechanical test report (mechanical test section).

6.8.7.11 If the vendor demonstrates that electrical or mechanical runout is present, a maximum of the level from Equation (11) or 6.35 μm (0.25 mil), whichever is greater, shall be vectorially subtracted from the vibration signal measured during the factory test.

6.8.7.12 Where shaft treatment such as metalized aluminum bands have been applied to reduce electrical runout, surface variations (noise) may cause a high frequency noise component that does not have an applicable vector. The nature of the noise is always additive. In this case, the noise shall be mathematically subtracted.

In SI units:

$$R_{out} = \frac{25.4}{4}\sqrt{\frac{12,000}{N_{mc}}} \tag{11a}$$

In USC units:

$$R_{out} = \frac{1}{4}\sqrt{\frac{12,000}{N_{mc}}} \tag{11b}$$

where

R_{out} is the rotor runout, μm (mil);

N_{mc} is the maximum continuous speed, rpm.

6.9 Bearings and Bearing Housings

6.9.1 Bearings—General

● **6.9.1.1** If specified, active magnetic bearings shall be provided, otherwise pressure-lubricated hydrodynamic radial and thrust bearings shall be provided. Detailed design of active magnetic bearings shall be mutually agreed between the steam turbine vendor and the purchaser.

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

6.9.1.3 The integrity of babbitt-pad interface (bond) in each pad of hydrodynamic radial and thrust bearings shall be checked by ultrasonic inspection. Liquid penetrant inspection shall be used to check side separation (separation on the edge) of babbitt in each bearing pad. The acceptance criteria for these inspections shall be agreed by the purchaser and the vendor.

6.9.1.4 Thrust bearing and radial bearings shall be:

a) suitable for operating at barring and turning gear speeds without damaging the babbitt lining;

b) designed for reverse rotation in mechanical drive applications, for short durations (i.e. following turbine trip) without damaging the babbitt lining;

c) designed to prevent damage from load transfer to critical bearing housing surfaces that are not considered normal wearing surfaces.

6.9.1.5 As a design criterion, thrust and radial bearing metal temperatures shall not exceed 100 °C (212 °F) at all specified operating conditions with a maximum inlet oil temperature of 50 °C (120 °F).

6.9.1.5.1 For ambient conditions which exceed 43 °C (110 °F) or if the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow, and allowable temperature rise.

6.9.2 Hydrodynamic Bearings

6.9.2.1 Hydrodynamic radial bearings shall be in accordance with 6.9.2.1.1 through 6.9.2.1.4.

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

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

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

6.9.2.1.4 Bearings shall be designed to prevent incorrect positioning.

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

6.9.2.3 Hydrodynamic thrust bearings shall be in accordance with 6.9.2.3.1 through 6.9.2.3.10.

6.9.2.3.1 Thrust bearings shall be of steel-backed, babbitted multiple-segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting-pad type, incorporating a self-leveling feature that ensures that each pad carries an equal share of the thrust load with minor variation in pad thickness.

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

6.9.2.3.3 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. If replaceable collars are furnished, they shall be shrunk on, and positively locked to, the shaft to prevent fretting.

6.9.2.3.4 Both faces of thrust collars shall be finished to a surface roughness not exceeding 0.4 μm (16 μin.) Ra or better. The axial total indicated runout of either face shall not exceed 13 μm (0.0005 in.).

6.9.2.3.5 Thrust bearings shall be selected such that under any operating condition the load does not exceed 50 % of the bearing manufacturer's ultimate load rating.

NOTE 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 location of maximum temperature on the pad, whichever load is less.

6.9.2.3.6 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 at design and at twice the design internal clearances;

b) step thrust from all diameter changes;

c) stage reaction and differential pressure on rotating blade rows;

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

e) external loads from the driven equipment in accordance with 6.9.2.3.7 and 6.9.2.3.8.

NOTE An individual stage pressure drop can change with the operating conditions. The combined pressure drop from all stages at a specific operating condition determines the total stage reaction load on the thrust bearing.

6.9.2.3.7 Thrust forces from metallic flexible element couplings shall be calculated based on the maximum allowable deflection permitted by the coupling vendor.

6.9.2.3.8 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.

6.9.2.3.9 The following factors shall be included in sizing thrust bearings for each specific turbine 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 sizing of thrust bearings shall be reviewed and approved by the purchaser.

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

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

6.9.3 Bearing Housings

6.9.3.1 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.

6.9.3.1.1 The seals and deflectors shall be made of spark resistant materials.

6.9.3.1.2 The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

6.9.3.2 Bearing housing support structures bolted to casings shall be steel.

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

6.9.3.4 Provision shall be made for mounting two non-contacting 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.

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

6.9.3.6 Bearing housings shall be arranged to minimize foaming. The drain system shall be sized to maintain the oil and foam level below shaft end seals.

6.9.3.7 Bearing support system parts (bearing housings, bearing carriers, bearing brackets, etc.) shall be separable from the casing, axially split, nonpressurized (vented to atmosphere), and furnished with plugged connections for dry air or inert gas purge to any atmospheric labyrinth seals.

6.9.3.8 Bearing housings shall have a metal-to-metal joint whose halves are located by means of cylindrical dowels.

6.10 Lubrication and Control-oil System

6.10.1 Hydrodynamic bearings and their bearing housings shall be arranged for pressurized oil lubrication using a mineral oil in accordance with ASTM D4304 or ISO 8068:2006.

● **6.10.2** If specified, the turbine vendor shall furnish a pressurized lubrication and control-oil system in accordance with API 614 Part 1 and Part 2.

6.10.3 The pressurized oil system shall supply oil at a suitable pressure or pressures, as applicable, to the following:

a) the bearings of the turbine and of the driven equipment;

b) any continuously lubricated couplings;

c) the control-oil system;

d) the turbine shutdown system.

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

a) define the steady and transient lube oil and control-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 electrically operated turning gear.

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

6.10.5.1 The vendor shall state the preferred oil and its required properties.

● **6.10.5.2** The purchaser may specify a preferred oil for manufacturer's approval. The preferred mineral oil viscosity shall correspond to ISO 3448 Grade 32.

NOTE Operating conditions can need higher viscosity oil.

6.11 Materials

6.11.1 General

6.11.1.1 Materials of construction shall be selected for the operating and site environmental conditions specified (see 6.1.19).

6.11.1.2 The material specification of all major components shall be clearly stated in the vendor's proposal. Materials shall be identified by reference to applicable international standards, including the material grade. If international standards are not available, internationally recognized national standards may be used. 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.

NOTE 1 National standards such as ANSI, DIN, and BS are examples of internationally recognized national standards. Examples of internationally recognized "other standards" include API, NEMA, etc.

NOTE 2 Annex K includes typical material specifications for steam turbine components.

6.11.1.3 The vendor shall identify the optional tests and inspection procedures that are necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal.

6.11.1.4 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.

NOTE Corrosion-resistant materials are needed to prevent binding or seizure.

6.11.1.5 Minor parts such as nuts, springs, washers, gaskets, and keys shall have corrosion resistance suitable for their environment.

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

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

6.11.1.7 If mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound that is suitable for the operating temperature of the mating parts and compatible with the material(s) and steam.

NOTE The torque loading values needed to achieve the necessary preload vary considerably depending on if antiseizure compounds are used on the threads.

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

6.11.1.9 Pressure-containing parts shall be steel.

6.11.1.9.1 Alloy steels shall be used for maximum steam temperatures exceeding 410 °C (770 °F).

6.11.1.9.2 Exhaust casing of noncondensing turbines shall be considered as pressure-containing based on the maximum specified exhaust pressure and the maximum no-load exhaust temperature.

NOTE Exhaust casing of condensing turbine is not considered as pressure containing.

6.11.1.9.3 Exhaust casing of condensing turbines shall be made of steel.

NOTE 1 Steel exhaust casings can reduce the probability of liberated rotor parts penetrating the casing.

NOTE 2 Erosion or other damage in cast iron exhaust casings can be difficult to repair during turbine outage.

6.11.1.10 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.

6.11.1.11 Positive Material Identification (PMI)

6.11.1.11.1 PMI testing shall be in accordance with 6.11.1.11.2 through 6.11.1.11.8.

● **6.11.1.11.2** If specified, alloy steel items shall be subject to PMI testing per the turbine datasheet.

● **6.11.1.11.3** In addition to the alloy steel components, other materials, welds, fabrications, and piping shall be PMI tested as specified on the turbine datasheet.

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

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

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

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

NOTE 2 API 578, ASTM E572, and ASTM E1476 include additional information on PMI testing.

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

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

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

6.11.2 Castings

6.11.2.1 Castings shall be 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 (e.g. solvent cleaning), or other standard methods. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

6.11.2.2 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.

NOTE A chaplet is a metal support that holds a casting core in place within a mold. Molten metal solidifies around a chaplet and fuses it into the finished casting.

6.11.2.3 Pressure-containing ferrous castings shall only be repaired as specified in a) through c).

a) Weldable grades of steel castings shall be repaired by welding, using a qualified welding procedure based on the requirements of Section VIII, Division 1, and Section IX of the ASME BPVC or other internationally recognized standard as approved by the purchaser. After major weld repairs, and before hydro test, the complete repaired casting shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.

b) If defects in iron castings exist and are within allowed repair limits of ASTM A395, plugging is an acceptable repair method. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

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

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

6.11.2.5 All ductile iron castings shall be produced in accordance with ASTM A395 or other internationally recognized standard as approved by the purchaser. Production of the castings shall also conform to the conditions specified in 6.11.2.5.1 through 6.11.2.5.4.

6.11.2.5.1 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. Graphite nodules shall be classified under microscopic examination and shall be in accordance with ASTM A247. There shall be no intercellular flake graphite.

NOTE Critical sections are typically heavy sections, section changes, high-stress points such as drilled lubrication points, and flanges. Normally, bosses and similar sections are not considered critical sections of a casting. If critical sections of a casting have different thicknesses average size keel or Y blocks can be selected in accordance with ASTM A395.

6.11.2.5.2 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. All three specimens shall have an impact value greater than or equal to 12 joule (9 ft-lbf), and the mean of the three specimens shall be greater than or equal to 14 joule (10 ft-lbf) at room temperature.

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

6.11.2.5.4 Brinell hardness test shall be made in addition to hardness test on keel or Y blocks in accordance with 6.11.2.5.1 and as specified in a) through c).

a) Be performed on the actual casting at feasible critical sections such as section changes, flanges, and other accessible locations.

b) Sufficient surface material shall be removed before hardness tests are made to eliminate any skin effect.

c) Be performed at the extremities of the casting at locations that represent the sections poured first and last.

6.11.3 Welding

6.11.3.1 Welding of piping, pressure-containing parts, rotating parts and other highly stressed parts, weld repairs and any dissimilar-metal welds shall be performed and inspected by operators and procedures qualified in accordance with Section VIII, Division I, and Section IX of the ASME BPVC or another purchaser approved standard such as ISO 9606 and ISO 15607 for welding procedures and welder qualification.

6.11.3.2 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 BPVC or ISO 10721-2 or other purchaser approved welding standard.

6.11.3.3 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 and conform to the requirements in 6.11.3.3.1 and 6.11.3.3.2.

6.11.3.3.1 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.

6.11.3.3.2 Procedures for major repairs shall be subject to review and approval by the purchaser before any repair is made.

6.11.3.4 Pressure-containing casings made from wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.11.3.4.1 through 6.11.3.4.4.

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

6.11.3.4.2 Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after PWHT. The quality control of welds that are inaccessible upon completion of the fabrication shall be agreed prior to fabrication.

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

6.11.3.4.4 Casings fabricated from materials that, according to Section VIII, Division I, of the ASME BPVC or other internationally recognized standard as approved by the purchaser requiring PWHT, shall be heat treated regardless of thickness.

● **6.11.3.4.5** If specified, in addition to the requirements of 6.11.3.1, specific welds shall be subjected to 100 % radiography, magnetic particle inspection, or liquid penetrant inspection.

6.11.3.5 Connections welded to pressure casings shall be installed as specified in 6.11.3.5.1 through 6.11.3.5.4.

● **6.11.3.5.1** 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 post-weld heat treatments.

6.11.3.5.2 All welds shall be heat treated in accordance Section VIII, Division 1, Sections UW-10, UW-40, of the ASME BPVC.

6.11.3.5.3 PWHT, if required, shall be performed after all welds, including piping welds, have been completed.

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

NOTE Low-carbon austenitic stainless steel is identified by the letter L after the numerical designation such as 304L or 316L.

6.12 Nameplates and Rotation Arrows

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

6.12.2 Rotation arrows shall be cast-in or attached to each major item of the rotating equipment train at a readily visible location. A rotation arrow shall be located on the exterior of the thrust-bearing housing.

6.12.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper (UNS N04400) alloy. Attachment pins shall be of the same material as the nameplate. Welding to attach the nameplate to the casing is not permitted.

6.12.4 The following data shall be clearly stamped or engraved on the nameplate, in units consistent with the datasheet:

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) serial number;

d) size, type, and model;

e) year shipped;

f) rated power and rated speed;

g) 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 allowable inlet steam temperatures and pressures;

l) normal and maximum allowable exhaust steam pressures;

m) maximum exhaust casing pressure;

n) normal and maximum allowable extraction steam pressure (if applicable);

o) normal and maximum allowable induction steam temperature and pressure (if applicable);

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

6.12.5 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 Accessories

7.1 Turning Gear

● **7.1.1 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 due to uneven heating or cooling during turbine starting and stopping.

7.1.2 Energizing of power operated turning gear shall be possible only after lube oil pressure has been established.

7.1.3 The turning gear shall automatically disengage when the turbine rotor accelerates during start-up.

7.1.4 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.

● **7.1.5** The type of turning device shall be specified by the purchaser. It may be driven by electrical motor, hydraulic motor, or pneumatic motor. Provision shall be made to permit manual operation of the turning gear or rotor.

7.1.6 The turning gear rotational speed and torques including breakaway torque and maximum torque capability of the turning gear driver shall be agreed by the purchaser and the vendor.

NOTE 1 These factors are dependent on duration of use, minimum speed permitted for the turbine and the driven equipment, and the lube oil supply conditions.

NOTE 2 A separate auxiliary lube oil pump can be provided to supply required oil flow to turbine and driven equipment bearings during operation of the turning gear.

● **7.1.7** If specified, a turning gear operating station with associated control features, as detailed by the purchaser, shall be provided.

7.1.8 Automatic engagement shall not occur in the event of reverse rotation following a turbine trip. Turning gear shall be designed to automatically disengage to prevent damage during reverse rotation events.

7.2 Relief Valves

7.2.1 General

7.2.1.1 Relief valves shall have steel bodies.

7.2.1.2 The vendor shall furnish the relief valves that are to be installed on equipment or on vendor supplied piping.

7.2.1.3 The purchaser shall furnish other relief valves to be installed in the purchaser's piping. The vendor shall advise the purchaser of the flow rate, set pressure, and temperature for purchaser's use in relief valve sizing and selection.

7.2.1.4 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.

7.2.1.5 The sizing, selection, and installation of relief valves shall meet the requirements of API 520, Parts I and II. Relief valves shall be in accordance with API 526.

7.2.1.6 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 to protect the turbine and supplied auxiliary systems. Relief valve sizes and set pressures shall take account of all possible modes of equipment failure.

7.2.2 Turbine Relief Valves

7.2.2.1 The relief valve set pressure(s) shall be set no higher than the casing maximum allowable working pressure.

7.2.2.2 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 shell.

7.3 Couplings

7.3.1 Couplings and coupling-to-shaft junctures shall conform to API 671.

7.3.2 Unless otherwise specified, couplings shall be of metallic flexible element type.

7.3.3 The make, sizing, and mounting arrangement shall be agreed by the purchaser and the vendors of the turbine and driven equipment (see 6.6.1.5).

7.3.4 Couplings shall be supplied by the vendor with unit responsibility.

7.3.5 If required for uncoupled turbine operation, the coupling vendor shall provide an idling adaptor (solo plate) for the drive end of the coupling. The idling adaptor shall center and maintain balance of the coupling. An idling adaptor may also be designed to serve as a moment (mass) simulator.

7.3.6 If a turbine coupling hub is provided, it shall be mounted at the turbine vendor's facility before equipment is shipped.

NOTE Coupling spacer assemblies are usually installed in the field.

● **7.3.7** If specified, the coupling vendor shall provide plug and ring gauges and lapping tools in accordance with API 671 for tapered-bore coupling hubs.

7.4 Guards

Unless otherwise specified, guards over couplings between turbine and driven equipment shall be supplied and mounted by the vendor with unit responsibility. Coupling guards shall meet all requirements of API 671, Annex H.

NOTE For soleplate mounted equipment or large turbine driven trains shipped in components, installation of guards at site can be needed.

7.5 Gland Vacuum System

7.5.1 A gland vacuum system shall be furnished by the turbine vendor. It shall include a gland condenser and steam ejector sized for three times the expected flow with "as new" shaft seal clearances (see 6.7.1.6 and 6.7.1.7).

7.5.2 The gland 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 (0.60 in.), and fixed tube sheets with water on the tube side. U-tubes shall not be used.

7.5.2.1 The water side (tube side) shall conform to the requirements of 6.1.10.

7.5.2.2 The shell side shall be designed for both full vacuum and gauge pressure of 500 kPa (75 psi).

7.5.3 The steam ejector shall have a steel body and a replaceable stainless steel steam nozzle.

● **7.5.4** If specified, the turbine vendor shall provide a vacuum pump in place of a steam ejector.

7.6 Mounting Plates

7.6.1 General

● **7.6.1.1** 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 L.

7.6.1.2 Mounting plates (baseplates and soleplates) shall comply with the requirements of 7.6.1.3 through 7.6.1.17.

7.6.1.3 The upper and lower surfaces of mounting plates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 3.2 μm (125 μin.) R_a or better.

7.6.1.4 The mounting plate or plates shall be furnished in accordance with 7.6.1.4.1 through 7.6.1.4.6.

7.6.1.4.1 Horizontal (axial and lateral) jackscrews, the same size or larger than the vertical jackscrews in the turbine feet.

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

7.6.1.4.3 Precautions shall be taken to prevent vertical jackscrews in the turbine feet from marring the shimming surfaces such that shimming, or alignment issues are not created.

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

7.6.1.4.5 Arrangements shall be proposed for the turbine that is too heavy to be lifted or moved horizontally using jackscrews.

7.6.1.4.6 Alignment jackscrews shall be plated for rust resistance.

7.6.1.5 Turbine supports shall be designed to limit the relative displacement of the shaft end caused by the worst combination of steam pressure, torque, and allowable piping stress, to 50 μm (0.002 in.) (see 6.5 for external forces and moments, i.e. allowable piping loads).

7.6.1.6 Turbine pedestals shall be designed and fabricated to permit the turbine to be moved using horizontal jackscrews.

7.6.1.7 Epoxy grout shall be used for turbine mounting plates.

7.6.1.7.1 The turbine vendor shall blast-clean in accordance with SSPC-SP6/NACE No. 3 or ISO 8501 Grade Sa2 all grout contact surfaces of the mounting plates and coat those surfaces with a primer compatible with specified epoxy grout.

7.6.1.7.2 The turbine vendor shall advise the purchaser the actual primer used. The grout vendor should be consulted to ensure proper field preparation of the mounting plate for satisfactory bonding of the grout to the grout primer.

NOTE 1 Epoxy primers have a limited life after application.

NOTE 2 Several primers can be used for the same epoxy grout and different field preparation for grouting can be needed for these primers.

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

7.6.1.9 The anchor bolts shall not be used to fasten equipment to the mounting plates.

NOTE This is to prevent disturbing the attachment to the foundation when removing the equipment.

7.6.1.10 Mounting plates shall conform to the following:

a) Mounting plates shall not be drilled for equipment to be mounted by others.

b) Mounting plates shall be supplied with leveling screws. A leveling screw shall be provided near each anchor bolt. If the equipment and mounting plates are too heavy to be lifted using leveling screws, alternate methods shall be provided by the turbine vendor. The design of the alternate method shall be included in the proposal.

c) Outside corners of mounting plates that are embedded in the grout shall have 50 mm (2 in.) minimum radiused outside corners in the plan view. Embedded edges shall be rounded to prevent the potential of cracking the grout.

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

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

NOTE For Item e), this requirement allows handling of shims and mounting level or laser type instruments to check alignment.

7.6.1.11 The alignment shims shall be provided by the turbine vendor in accordance with API 686, Section 7 and shall straddle the hold down bolts and vertical jackscrews and be at least 6 mm ($^1/_4$ in.) larger on all sides than the equipment feet.

7.6.1.12 Anchor bolts shall be furnished by the purchaser.

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

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

7.6.1.15 Grouted mounting plates shall be sized to limit the static loading to 690 kN/m2 (100 psi) on the grout.

7.6.1.16 Diametrical clearance between anchor bolts and the anchor bolt holes in the mounting plates shall be a minimum of 6 mm ($^1/_4$ in.).

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

7.6.2 Baseplate

● **7.6.2.1** If a baseplate has been specified, the purchaser shall indicate the major equipment to be mounted on it.

7.6.2.1.1 A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor agree that it may be fabricated in multiple sections.

7.6.2.1.2 Multiple-section baseplates shall have machined and doweled mating surfaces that shall be bolted together to ensure accurate field reassembly.

7.6.2.1.3 A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) may have to be fabricated in multiple sections because of shipping restrictions.

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

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

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

● **7.6.2.5** If specified, the baseplate shall be designed to facilitate the use of optical, laser based or other instruments for accurate leveling in the field. The details of such facilities shall be agreed by the purchaser and vendor.

7.6.2.5.1 If leveling pads or targets are provided, they shall be accessible with the baseplate on the foundation and the equipment mounted. The leveling pads and targets shall have removable protective covers.

7.6.2.5.2 Pads or targets shall be located close to the machinery support points. For baseplates longer than 6 m (20 ft), additional pads shall be located at intermediate points.

● **7.6.2.6** If specified, the baseplate shall be designed for column mounting (that is, of sufficient rigidity to be supported at only specified points) without continuous grouting under structural members. The baseplate design shall be agreed by the purchaser and the vendor. Design suitability shall be verified by finite element analysis or similar design analysis tool.

7.6.2.7 The baseplate shall be provided with lifting attachments meeting the requirements of 7.6.2.7.1 through 7.6.2.7.6.

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

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

NOTE Design of lifting attachments can be in accordance with standards such as ASME BTH-1, Design of Below-the-Hook Lifting Devices.

7.6.2.7.3 Unless otherwise agreed, baseplates shall be designed for lifting with all equipment mounted.

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

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

7.6.2.7.5 Lugs or trunnions that are attached by welding shall have continuous welds and shall be 100 % NDE tested in accordance with the applicable code.

7.6.2.7.6 Removable lugs or commercially available specialty products such as pivot type hoisting rings shall be provided with the purchaser's approval.

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

7.6.2.8 For accessibility and grouting, the baseplate shall be designed per 7.6.2.8.1 through 7.6.2.8.5.

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

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

7.6.2.8.3 The grout holes shall be located to permit grouting under all load-carrying structural members. The holes shall be accessible for grouting with the equipment installed.

7.6.2.8.4 The holes shall have 13 mm ($^1/_2$ in.) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 3 mm ($^1/_8$ in.) shall be provided.

7.6.2.8.5 Vent holes at least 13 mm ($^1/_2$ in.) in size shall be provided at the highest point and located to vent the entire cavity in each bulkhead section of the baseplate.

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

7.6.2.10 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

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

7.6.2.11 Two ground clips or pads shall be welded to the baseplate at diagonally opposed corners. These clips or pads shall be of the same material as the baseplate and accommodate a 13 mm ($^1/_2$ in. UNC) bolt.

7.6.2.12 All baseplate machinery mounting surfaces shall meet the criteria in a) through e).

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

b) They shall be machined to a finish of 6.3 μm (250 μin.) *Ra* or better.

c) They shall have each mounting surface machined within a flatness of 40 μm per linear meter (0.0005 in. per linear foot) of mounting surface.

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

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

7.6.2.13 The tolerances in 7.6.2.12 shall be recorded and verified by placing the baseplate in unrestrained condition on a flat machined surface at the place of fabrication.

● **7.6.2.14** If specified, subsoleplates shall be provided by the turbine vendor.

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

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

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

7.6.3 Soleplates and Subsoleplates

7.6.3.1 If soleplates are specified, they shall meet the requirements of 7.6.3.2 through 7.6.3.5 in addition to those of 7.6.1.

NOTE Refer to Annex L for a typical sketch.

7.6.3.2 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.

7.6.3.3 If subsoleplates have been specified, they shall be steel plates at least 25 mm (1 in.) thick. The finish of the subsoleplates mating surfaces shall match that of the soleplates (see 7.6.1.3).

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

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

7.7 Controls and Instrumentation

7.7.1 General

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

● **7.7.1.2** The purchaser shall specify that controls and instruments are designed for outdoor or indoor installation.

● **7.7.1.3** The purchaser shall specify required construction and installation standards for controls.

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

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

NOTE Special considerations for protection can be needed for instrumentation working below −20 °C (−4 °F) or above 55 °C (131 °F).

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

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

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

a) construction requirements;

b) door and cover securement;

c) corrosion resistance;

d) effects of icing;

e) gasket aging and oil resistance;

f) coolant effects.

The Type designation of NEMA specifies requirements for these additional performance protections. For this reason, the IEC enclosure IP Code designations are not converted to enclosure NEMA Type numbers (NEMA publication “A Brief Comparison of NEMA 250 and IEC 60529”).

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

7.7.1.7 Instrumentation and controls shall be designed and manufactured for use in the area classification (class, group, and division or zone) specified in 6.1.13.

7.7.1.8 All conduit, armored cable and supports shall be designed and installed so that they are easily removable without damage and shall be located so that they do not hamper removal of bearings, turbine gland seals, or equipment internals.

7.7.1.9 Where applicable, controls and instrumentation shall conform to API 551.

7.7.2 Control Systems

7.7.2.1 Turbine Governing System

7.7.2.1.1 The governor system shall be the primary system necessary to match the turbine output to the application. The governor system shall include:

a) speed sensors;

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

c) actuator(s);

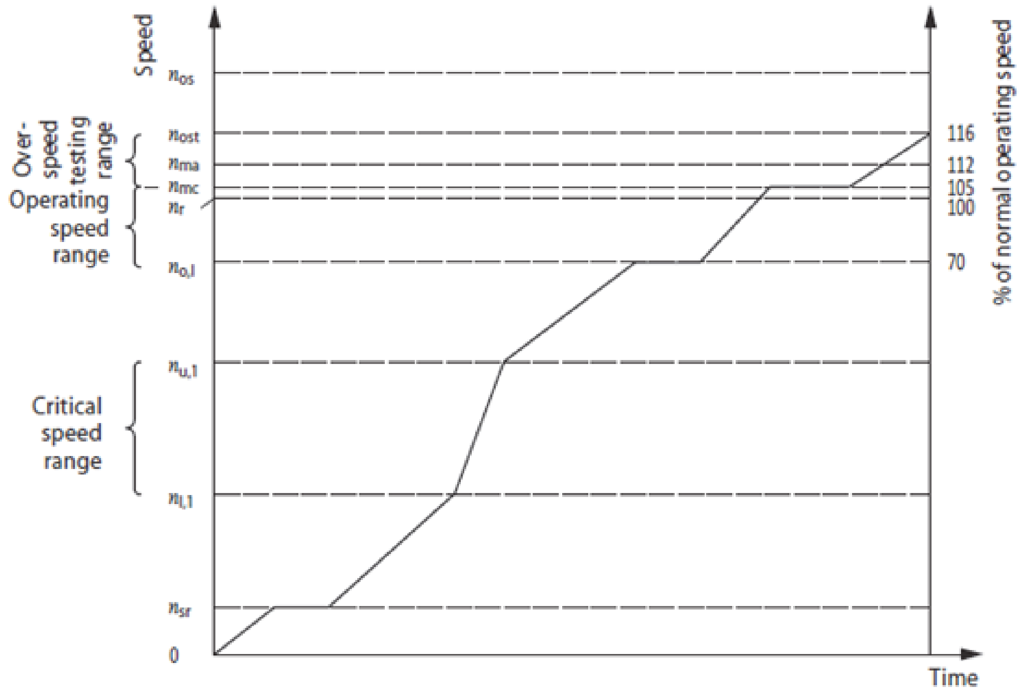
d) position feedback transducers;

e) governor-controlled valve(s).

7.7.2.1.2 If the vendor provides the governor system with the turbine, the vendor shall have unit responsibility for the entire governor system.

7.7.2.1.3 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 4.



Key

N_{sr}	slow roll speed	n_{mc}	maximum continuous speed
$n_{l,1}$	minimum critical speed	n_{ma}	maximum allowable speed (see 3.1.26)
$n_{u,1}$	maximum critical speed	n_{ost}	overspeed trip speed typically 116 % n_r
$n_{o,l}$	minimum operating speed	n_{os}	maximum temporary overshoot speed
n_r	rated operating speed		

Figure 4—Mechanical Drive Turbine Ramp Speeds

7.7.2.1.4 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 is not necessary if the turbine is used in tandem with a main driver and the main driver controls the speed of the complete train.

7.7.2.1.5 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 control and logic functions may reside in the same control system.

7.7.2.1.6 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 7.7.2.1.11.

7.7.2.1.7 Additional control functions not related to the governor system shall not degrade the performance.

7.7.2.1.8 The governor system shall be protected from inadvertent changes that affect performance or safe operation.

7.7.2.1.9 The governor control system shall be powered by a purchaser-supplied uninterruptible electrical power source.

7.7.2.1.10 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.

7.7.2.1.11 The governing system shall comply with the requirements of Items a) through c) below.

a) The speed regulation at steady state rated speed, rated power output and rated steam inlet and exhaust conditions shall not exceed 0.5 %. Speed regulation is the amount of change in sustained speed when the power output of the turbine is gradually reduced from rated power to zero power and is defined in Equation (12).

$$\frac{n_{PO} - n_{PR}}{n_{PR}} \times 100\,\% \qquad (12)$$

where

n_{PO} is the speed at zero power (zero load) output, rpm;

n_{PR} is the speed at rated power output, rpm.

b) The steady state speed variation at constant load, rated speed, rated power output, and rated steam inlet and exhaust conditions shall not exceed 0.25 %. Speed variation is the total amount of speed change from the speed set point and is defined in Equation (13).

$$\frac{n_{i,max} - n_{i,min}}{2 \times n_r} \times 100\,\% \qquad (13)$$

where

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

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

n_r is the rated speed, rpm.

c) The maximum speed rise shall not exceed 7 % of the rated speed. The maximum speed rise is the maximum momentary increase in speed when the turbine is developing rated power output at rated speed, and the load is suddenly and completely reduced to zero. Maximum speed rise is defined in Equation (14).

$$\frac{n_{max} - n_r}{n_r} \times 100\,\% \qquad (14)$$

where

n_{max} is the maximum speed at zero power (zero load) output, rpm;

n_r is the rated speed, rpm.

NOTE 1 Speed variation is the total amount of speed change from the speed setting when the turbine is operating in steady state rated conditions of inlet pressure, inlet temperature, and exhaust pressure and rated speed.

NOTE 2 This paragraph does not apply to generator drives in droop mode.

NOTE 3 The percentage limits in Items a) through c) can be different when turbine operates at maximum continuous speed.

7.7.2.1.12 The speed governor system shall include at least two speed sensors dedicated for speed control. The speed sensors shall not to be shared with the overspeed shutdown system.

7.7.2.1.13 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.

7.7.2.1.14 The failure of any speed-sensing element shall initiate an alarm only. The failure of all elements shall initiate a shutdown.

7.7.2.1.15 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 under the control of speed governor (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) shutdown upon receiving shutdown commands from the overspeed shutdown system and, or process controls system;

j) manually activated maximum speed set point override with controlled access for testing the overspeed shutdown system.

7.7.2.1.16 For mechanical drive application, the speed of the turbine shall vary linearly with the set point signal. An increase in set point signal shall increase turbine speed.

7.7.2.1.17 The speed set point signal shall act to adjust the set point of the governor system.

7.7.2.1.18 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.

7.7.2.1.19 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.

7.7.2.1.20 The governing system shall be designed to control the turbine speed at slow roll speed 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.

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

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

7.7.2.1.23 The level of redundancy (e.g. duplex system) and fault tolerance (e.g. triple modular redundant system) shall be as required to meet the uninterrupted service expectation.

7.7.2.1.24 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.

7.7.2.1.25 Facilities shall be provided to allow replacement of a failed governor circuit board or power supply without affecting the continuous operation of the governor.

7.7.2.2 Electronic Overspeed Detection System

7.7.2.2.1 An overspeed detection system based on three independent measuring circuits and two-out-of-three (2-o-o-3) voting logic in accordance with API 670 shall be supplied.

7.7.2.2.2 A multi-toothed speed-sensing surface shall be provided as specified in 6.6.4 and API 670. This surface may be shared by the speed governor, overspeed shutdown system, and tachometer.

● **7.7.2.2.3** If specified, the overspeed trip system shall be supplied with an acceleration trip function.

7.7.2.3 Turbine Overspeed Shutdown (Trip) System

7.7.2.3.1 An overspeed trip system capable of shutting down the turbine shall be provided. The turbine overspeed trip 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).

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

7.7.2.3.3 If the turbine vendor provides the overspeed trip system with the turbine, the turbine vendor shall have unit responsibility for this entire system.

7.7.2.3.4 If the overspeed trip system is not furnished by the turbine vendor, the turbine vendor shall provide the response time of the trip systems components and review, and comment on the proposed system.

7.7.2.3.5 The turbine overspeed trip system shall be powered by a purchaser-supplied uninterruptible electrical power source.

7.7.2.3.6 The turbine overspeed trip 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.

● **7.7.2.3.7** If specified, the design of the turbine overspeed trip system shall conform to IEC 61508/IEC 61511.

7.7.2.3.8 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 combined trip and throttle valve, the governor valves can be opened prior to starting the turbine.

7.7.2.3.9 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).

7.7.2.3.10 The overspeed trip function shall be part of the turbine shutdown system. The overspeed trip 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.

7.7.2.3.11 The turbine overspeed trip system shall prevent the turbine rotor speed from exceeding the turbine vendor-provided maximum momentary overshoot speed limit. 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 (nost) is 116 % of the turbine rated speed or driven equipment rated speed, whichever is less.

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

NOTE 1 Even when the emergency trip valve is closed, a turbine exhausting to subatmospheric 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.

NOTE 2 For turbines exhausting to a common condensing system, air admission is not feasible and more positive emergency trip valves or other provision can be needed.

7.7.2.3.13 On controlled extraction turbines, the vendor shall supply a nonreturn valve on each extraction line, equipped with a fail-closed actuator to assist in closing the valve. The actuator on these valves shall be actuated by the turbine shutdown system.

7.7.2.3.14 The vendor (manufacturer), model, design, type, quantity, and location of the nonreturn valve(s) and all actuator(s) shall be agreed by the purchaser and the turbine vendor.

7.7.2.3.15 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 For nonreturn valves installed in piping below the turbine, low-point drains are usually provided 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 and usually need alternative actuation methods.

7.7.2.3.16 On turbines with uncontrolled extractions, two nonreturn valves in series shall be provided on each extraction complete with features defined in 7.7.2.3.13.

7.7.2.4 Electro-hydraulic Solenoid Valves

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

7.7.2.4.2 Solenoid valves shall be continuously rated with class H insulation, in accordance with IEC 60072.

7.7.2.4.3 Solenoid valves shall be de-energized to shutdown (i.e. fail safe). The solenoid valves shall be in parallel, be close to the trip valve(s) or combined trip and throttle valve(s), and have no other device between them and the trip valve(s) or combined trip and throttle valve(s) except test isolation valves. An example of a minimum acceptable configuration is shown in Figure 5.

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 can exist for long periods of time without being detected leaving the equipment unprotected.

● **7.7.2.4.4** 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 (2-o-o-3) or two-out-of-four (2-o-o-4) voted solenoid valve configurations.

NOTE Nuisance trips can occur with solenoid failure on systems with only a single solenoid.

7.7.2.4.5 The trip header oil dump solenoid valves shall be provided with facilities to allow testing of the solenoid valve function while the turbine is in operation.

7.7.2.4.6 The performed test(s) shall verify that the solenoid valves respond fast enough to meet the maximum momentary rotor overspeed calculation (see Annex E). An example of a minimum acceptable configuration is shown in Figure 5.

7.7.2.4.7 Monitoring facilities or procedures shall be implemented to ensure that 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 1 Monitoring facility can be automatic or manual.

NOTE 2 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 needed to exercise the spool or poppet and to verify that the valves will perform on demand.

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

7.7.2.4.9 Bleed valves in the trip solenoid valve system shall be sized so that in their fully open position the flow rate shall be too low to cause a trip.

7.7.2.4.10 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.

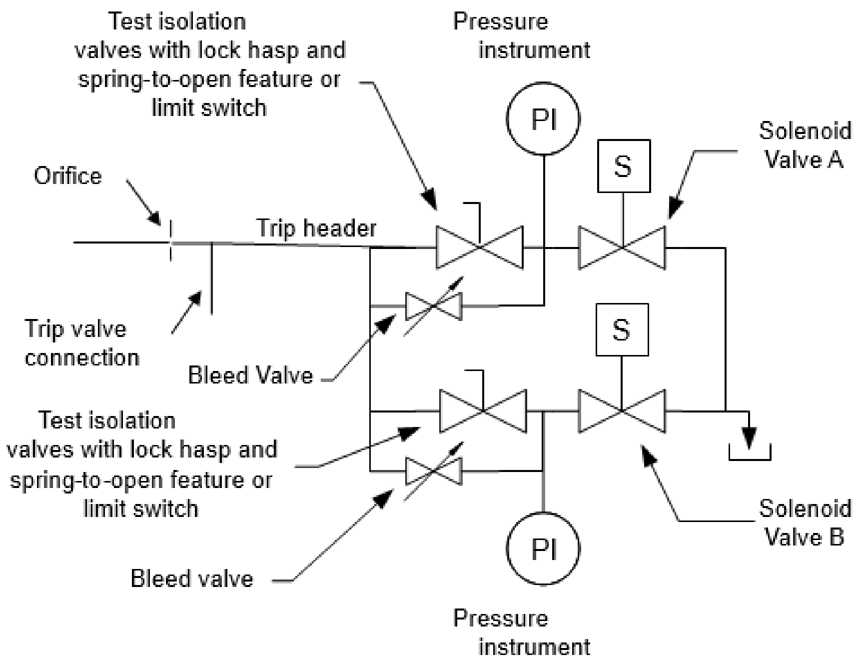


Figure 5—Trip Solenoid Valves—One-out-of-Two Configuration (1-o-o-2)

7.7.2.5 Trip Valves/Combined Trip and Throttle Valves

● **7.7.2.5.1** Separate independent trip valve or combined trip and throttle valves, as specified, shall be provided for each steam inlet including admission inlets. In this and the following sections, the term “trip valve” refers to both; a separate trip valve and a combined trip and throttle valve.

NOTE Dual steam inlets are provided on some turbines to reduce steam velocity in the steam chest.

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

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

7.7.2.5.4 Failure of trip valves to close when required is a common cause of turbine failure. Trip valves should be partially exercised at trip valve vendor-provided intervals [see 7.7.2.5.7, Item f)].

7.7.2.5.5 If 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 one or both trip valves.

7.7.2.5.6 Trip valves shall be designed to close by the action of a spring. Trip valves shall be held open by direct hydraulic means. Any shutdown signal shall cause trip valves to close.

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

7.7.2.5.7 The design of trip valves 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 containing 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 (exercising) capability that does not interrupt operation of the turbine (i.e. does not affect steam flow) if redundant valves are not specified; this arrangement shall prevent full closure during a partial stroking 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 Back-seated valve stem design can minimize leakage and fouling.

7.7.2.5.8 The trip valve steam strainer shall be designed to prevent in-service failure and conform to the requirements in a) through c) below.

a) The strainer shall be removable without dismantling any of the inlet steam piping.

b) The effective free area of the strainer shall be at least twice the cross-sectional area of the valve inlet connection.

c) The steam strainer shall be capable of withstanding a pressure differential at least equal to 25 % of the inlet pressure.

7.7.2.5.9 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.

7.7.2.5.10 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 6.6.2.1.3. The calculation methodology shall be in accordance with Annex E.

7.7.2.5.11 If a logic solver is provided by the purchaser, the response time of the logic solver shall not be more than that defined in API 670.

7.7.3 Instrument and Control Panels

● **7.7.3.1** If specified, a panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description.

● **7.7.3.1.1** The panel shall be freestanding, located on the base of the unit, or in another location, as specified. The instruments on the panel shall be clearly visible to the operator from the driver control point. If the panel contains lamps a lamp test push button shall be provided.

● **7.7.3.1.2** The instruments to be mounted on the panel shall be specified by the purchaser.

7.7.3.2 Panels shall be reinforced, self-supporting and closed on the top, bottom and sides. The front shall be steel plate at least 3 mm ($^1/_8$ in.) thick. Tops, bottoms, and sides shall be a minimum of 12-gauge in accordance with Table 4.

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

7.7.3.2.2 All instruments shall be flush mounted on the front of the panel and all fasteners shall be of corrosion resistant metal. All interior and exterior surfaces of carbon steel panels shall be prepared and coated with an industrial grade coating system.

Table 4—Material Thicknesses of 12-Gauge Steel

12-Gauge Steel	Material Thickness mm (in.)
Uncoated	2.7 (0.1046)
Galvanized	2.75 (0.1084)
Stainless steel	3 (0.1094)

NOTE Some European standard panels have different wall thickness.

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

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

7.7.3.4.1 Separate terminal boxes shall be supplied for segregation of the AC and DC electrical signals.

7.7.3.4.2 With purchaser's approval, one terminal box may be provided if it includes an internal barrier that separates the AC and DC wiring.

7.7.3.5 In addition to the requirements in 7.7.3.4, additional signal segregation by terminal boxes shall be specified.

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

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

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

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

7.7.4 Instrumentation

7.7.4.1 The following instrumentation shall be in accordance with API 614:

a) switches;

b) transmitters;

c) temperature indicators (gauges);

d) thermowells;

e) thermocouples and resistance temperature detectors (RTDs) (for in-line instruments only);

f) liquid level instruments;

g) pressure indicators;

h) oil sight flow indicators;

i) solenoid valves;

j) pressure-limiting valves and safety relief valves;

k) control valves and regulators.

NOTE Refer to API 614 for bulleted paragraph options to be selected regarding these instruments.

Bearing thermocouples and RTDs shall be in accordance with API 670.

7.7.4.2 Tachometers

7.7.4.2.1 Two electronic tachometers 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.

7.7.4.2.2 The speed signals may be obtained from the speed sensors provided for turbine governing or from independent sensors (see 7.7.2.1.12 and 7.7.2.1.13).

7.7.4.3 Vibration and Position Detectors

7.7.4.3.1 Vibration and axial position transducers shall be supplied, installed, and calibrated in accordance with API 670.

7.7.4.3.2 Vibration and axial position monitors shall be supplied and calibrated in accordance with API 670.

7.7.4.3.3 A bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

7.7.5 Alarms and Shutdowns

7.7.5.1 An alarm/shutdown system shall be provided which will initiate an alarm if any one of the specified parameters reaches an alarm point and will initiate shutdown of the turbine if any one of the specified parameters reaches the shutdown point.

● **7.7.5.2** The purchaser shall specify the alarms and shutdowns required to safeguard the turbine. As a minimum, these should include the following. An automated shutdown (trip) on overspeed detected by turbine shutdown system is a safety requirement.

a) Alarms:

   1) overspeed shutdown system fault;

   2) failure of any one governor speed sensor;

   3) low lube oil pressure;

   4) high exhaust pressure;

   5) high radial vibration;

   6) high axial displacement;

7) high bearing temperature;

8) low control oil pressure;

9) low/high extraction pressure;

10) low steam inlet temperature;

11) high exhaust temperature (condensing turbines);

12) governor fault;

13) turbine shutdown system response time slower than the response time as tested during installation;

14) turbine shutdown system trip oil header solenoid response time slower than the response time specified by the solenoid vendor;

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

b) Shutdowns:

1) overspeed detected by governor;

2) failure of all governor speed sensors;

3) low-low lube oil pressure;

4) high-high radial vibration (if specified);

5) high-high axial displacement;

6) high-high bearing temperature (if specified).

c) Automated shutdown (trip):

1) overspeed detected by turbine shutdown system (see 7.7.2.3).

7.7.5.2.1 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.

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

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

7.7.5.3 The turbine vendor shall advise the purchaser of any alarms and/or shutdowns in addition to those in 7.7.5.2 that are essential to safeguard the turbine.

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

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

7.7.5.5 The alarm/shutdown system shall comply with the requirements of 7.7.5.5.1 through 7.7.5.5.10.

NOTE It is accepted that with some systems, particularly those based on conventional direct acting instruments, complete compliance with the requirements of 7.7.5.5.1 through 7.7.5.5.10 cannot be achieved.

7.7.5.5.1 For every shutdown parameter an alarm shall be provided with the alarm point set at a lesser deviation from the normal condition than the associated shutdown point.

● **7.7.5.5.2** Any alarm parameter, reaching the alarm point, shall initiate an audible warning or flashing light or both as specified. It shall be possible to determine which parameter initiated the alarm.

● **7.7.5.5.3** Any shutdown parameter, reaching the shutdown point, shall cause the turbine to shut down and shall initiate an audible warning or a flashing light or both as specified, which shall be distinguishable from those associated with an alarm. It shall be possible to determine which parameter initiated the shutdown.

7.7.5.5.4 If any component of the alarm/shutdown system malfunctions, an alarm shall be initiated and shall be distinguishable from alarms resulting from malfunction of the equipment. To accomplish this, redundant sensors may be required.

7.7.5.5.5 If any malfunction of a component of the shutdown system results in the system being unable to recognize a shutdown condition, the equipment shall automatically shut down and an alarm shall be initiated. This alarm shall be distinguishable from shutdowns resulting from malfunction of the equipment (fail-safe system).

7.7.5.5.6 If a non-fail-safe system is specified, a failure that results in the system being unable to recognize an alarm condition shall also result in all other alarms and shutdowns remaining functional.

7.7.5.5.7 It shall be possible to test all components of the alarm system while the turbine is in operation. Such testing shall not require the disarming of any shutdown function.

7.7.5.5.8 With the exception of the combined trip and throttle valve, it shall be possible to test all components of the shutdown system while the turbine 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.

7.7.5.5.9 Trip valves that cannot be fully functionally tested may be tested partially, e.g. by partial stroke test (see 7.7.2.5.4).

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

NOTE This allows all alarms to be bypassed during testing of devices (switches).

● **7.7.5.6** If specified, the alarm/shutdown system shall incorporate a first-out annunciator facility to indicate which parameter first reached the alarm level and which parameter first reached the shutdown level, in the event that multiple alarms and/or shutdown result from a single initial event. Where this facility is not incorporated as part of an integrated control and monitoring system, a separate annunciator instrument shall be provided.

● **7.7.5.7** If specified, the alarm/shutdown system shall incorporate an event recorder to record the order of occurrence of alarms and shutdowns. Time resolution shall be not greater than 100 ms.

NOTE 1 The special event recorder associated with a DCS normally does not have a sufficiently fast scanning rate.

NOTE 2 Not all alarm malfunctions are detectable (e.g. channel states, open wiring, electrical noise, etc.)

7.7.5.8 The necessary valving and switches or bridging links (jumpers) or other approved protocol shall be provided to enable all instruments and other components, except shutdown sensing devices, to be replaced with the equipment in operation.

● **7.7.5.9** If specified, shutdown sensing devices shall be provided with valving, bridging links, or other approved protocol to allow replacement with the equipment in operation. Isolation valves for shutdown sensing devices shall be provided with means of locking the valves in the open position.

7.7.5.10 Annunciator

7.7.5.10.1 If a first-out annunciator feature has been specified in 7.7.5.6, whether as a separate instrument or incorporated into an integrated control and monitoring facility, the sequence of operation shall be as follows.

a) The first parameter to reach alarm or shutdown shall cause the flashing of a light and the sounding of an audible device.

b) The alarm or shutdown condition shall be acknowledged by operating an alarm silencing button, common to all alarms and shutdowns.

c) When the alarm or shutdown is acknowledged, the audible device shall be silenced but the light shall remain steadily lit as long as that alarm or shutdown condition exists.

d) If another parameter reaches an alarm or shutdown level the light shall return to the flashing condition and the audible device shall sound, even if the previous alarm/shutdown condition has been acknowledged but still exists.

7.7.5.10.2 If the first-out annunciator feature is provided by a separate instrument, it shall be mounted on a local panel. There shall be 25 % spare points and separate connections shall be provided for remote indication if any alarm operates or any shutdown operates.

7.7.5.11 Alarm and Trip Devices

For instrumentation for alarms and shutdowns, refer to API 614.

7.7.6 Electrical Systems

7.7.6.1 Motors, heaters, and instrumentation shall be suitable for the power supplies specified. A pilot light shall be provided on the incoming side of each supply to indicate that the circuit is energized. The pilot lights shall be installed on the control panel.

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

NOTE NFPA 780 contains information about installation of lightning protection systems. These systems can be needed in the areas where lightning strikes are prevalent.

7.7.6.3 Power and control wiring, located on, adjacent to, or connected to the equipment, shall be resistant to oil, heat, moisture, and abrasion and conform to the requirements specified in 7.7.6.3.1 through 7.7.6.3.4.

7.7.6.3.1 Stranded conductors shall be used if connected to or located on turbine or in other areas subject to vibration.

7.7.6.3.2 Measurement and remote-control panel wiring may be solid conductor.

7.7.6.3.3 The insulation over wiring/conductors shall be provided with an outer covering that shall be flame retardant, moisture, and heat resistant thermoplastic and abrasion resistant, if necessary.

7.7.6.3.4 Wiring shall be suitable for the local temperatures to be encountered.

NOTE Stranded wire is normally used to avoid failure due to fatigue in areas subject to vibration. Solid wire can be used in areas not subject to vibration.

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

7.7.6.5 Enclosures shall be provided for all terminal strips, relays, switches, and other energized parts to guard against accidental contact and shall meet the requirements specified in 7.7.6.5.1 through 7.7.6.5.3.

7.7.6.5.1 Electrical power wiring shall be segregated from instrument and control signal wiring both externally and, as far as possible, inside enclosures.

7.7.6.5.2 Inside enclosures that may be required to be opened with the equipment in operation, for example, for alarm testing or adjustment, shall be provided with secondary shields or covers for all terminal strips and other exposed parts carrying electrical potential in excess of 50 volts.

7.7.6.5.3 Maintenance access space shall be provided around or adjacent to electrical equipment or in accordance with the National Electrical Code, Article 110 or other internationally recognized standard as approved by the purchaser.

NOTE The 50-volt components inside a panel are meant to be in a secondary enclosure.

● **7.7.6.6** Electrical materials including insulation shall be corrosion resistant and nonhygroscopic. If specified for tropical location, materials shall be given the treatments to conform to 7.7.6.6.1 and 7.7.6.6.2.

7.7.6.6.1 Parts (such as coils and windings) shall be protected from fungus attack.

7.7.6.6.2 Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

7.7.6.7 Control, instrumentation, and power wiring that is not within a fully enclosed panel or other enclosure shall be in the form of armoured cable or shall be run in metal conduit as specified and shall meet the requirements specified in 7.7.6.7.1 through 7.7.6.7.3.

7.7.6.7.1 Cables shall be supported on cable trays supported to prevent damage from pedestrian traffic. Conduit shall be properly supported to avoid damage caused by vibration and isolated and shielded to prevent interference between different services.

7.7.6.7.2 Conduits may terminate (in the case of the leads to temperature elements, shall terminate) with a length of flexible metal conduit, long enough to facilitate maintenance without removal of the conduit.

7.7.6.7.3 In applications where conduit temperatures are above 60 °C (140 °F), the flexible conduit shall be 19 mm ($^3/_4$ in.) bronze hose with four-wall-interlocking construction and joints with packed-on heatproof couplings shall be used.

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

7.7.6.9 Alternating current (AC) and direct current (DC) circuits shall be clearly labeled, connected to separate terminal blocks, and isolated from each other.

7.7.6.10 Conduit drains shall be installed in all conduit low points for outdoor installations.

● **7.7.6.11** If specified, conduit drains shall be installed in all conduit low points for indoor installations.

7.8 Piping

7.8.1 General

7.8.1.1 Piping design, joint fabrication, examination, and inspection shall be in accordance with ASME B31.3 and shall conform to the requirements of API 614.

7.8.1.2 Auxiliary systems are defined as piping systems that are in the following services:

Group II

a) steam, including sealing steam;

b) instrument and control air;

c) drains and vents associated with above systems.

Group III

a) cooling water or cooling liquid;

b) drains and vents associated with this system.

Group IV

a) lubricating oil;

b) control oil;

c) drains and vents associated with above systems.

NOTE Group I includes auxiliary process fluids and solvents. They are not applicable to this standard.

Auxiliary piping systems and components shall be in accordance with the requirements of API 614.

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

7.8.1.4 The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, or any auxiliary base area.

7.8.1.4.1 The piping shall terminate with flanged connections at the edge of the base.

7.8.1.4.2 If soleplates are specified for the equipment train, the extent of the piping system at the equipment train shall be defined by the purchaser. The purchaser shall furnish only interconnecting piping between equipment groupings and off-base facilities.

7.8.1.5 The design of piping systems shall achieve the following:

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

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

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

d) elimination of air or vapor pockets by the use of valved vents or the use of nonaccumulating piping arrangements;

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

7.8.1.6 Piping shall be fabricated by bending and welding to minimize the use of flanges and fittings and shall comply with the requirements of 7.8.1.6.1 through 7.8.1.6.3.

7.8.1.6.1 Flanges are permitted only at equipment connections, at the edge of any base and for ease of maintenance. The use of flanges at other points is permitted only with the purchaser's specific approval.

7.8.1.6.2 Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas.

7.8.1.6.3 Pipe bushings shall not be used.

NOTE Pipe bushings are thin walled and can crack.

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

7.8.1.8 Piping systems furnished by the vendor shall be fabricated, installed in the shop, and properly supported. Pairs of adjacent bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centerline of the flange.

7.8.1.9 Auxiliary piping to the turbine shall have breakout spools or other flange connections to allow for maintenance and for removal of the entire turbine.

7.8.1.10 Provision shall be made for bypassing the bearings of all equipment in the train during oil system flushing operation.

NOTE Bypassing can be accomplished by using short spool pieces at the equipment.

7.8.2 Steam Piping

● **7.8.2.1** The extent of and requirements for steam piping to be supplied by the vendor shall be specified by the purchaser.

7.8.2.2 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.

● **7.8.2.3** 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.

NOTE Review of the design of piping and appurtenances typically considers the location of inlet trip valve(s), extraction valve(s), and safety valves with respect to the amount of trapped steam volume.

7.9 Special Tools

7.9.1 If special tools or fixtures are required to disassemble, assemble, or maintain the equipment, they shall be included in the quotation and furnished as part of the initial supply of the equipment.

7.9.1.1 For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between purchaser and vendor.

7.9.1.2 These special tools shall be used, and their use demonstrated, during shop assembly and post-test disassembly of the equipment.

7.9.2 If special tools are provided, each tool shall be labeled using metal stamps or have a permanently attached stainless steel tag to indicate its intended use.

7.9.2.1 Tools that do not exceed 1 m in length, width, or height and that weigh less than 40 kg (88 lb) shall be packaged in one or more rugged metal boxes and shall be marked "special tools for (tag/item number), box x of x."

7.9.2.2 Larger tools do not need to be boxed but shall have a stainless steel tag permanently attached to indicate both the intended use and the tag/item number of the equipment for which they are intended.

7.10 Insulation and Jacketing

7.10.1 The turbine vendor shall provide thermal insulation and jacketing for proper operation and for personnel protection. Turbine casing and components shall be insulated with a removable blanket type insulation.

7.10.2 Blanket insulation and jacketing shall be designed so that routine maintenance may take place without damage being done to the insulation.

7.10.3 Exposed surfaces in personnel access areas shall not exceed a temperature of 60 °C (140 °F).

7.10.4 Insulation shall be oil resistant and shall not contain asbestos.

7.10.5 If purchaser supplies turbine insulation, the turbine vendor shall advise the purchaser of the expected surface temperature of the casing and any special requirements.

NOTE ISO 13732-1:2006 explains the method for the assessment of human responses to contact with surfaces.

7.11 Enclosures

● **7.11.1** If specified, enclosure(s) shall be provided to meet the purchaser's acoustical, weatherproofing, safety, and/or fire protection requirements. Enclosure(s) shall be designed to ensure that the package meets the maintenance, operation, and service life requirements. An enclosure system may consist of the following:

a) an enclosure surrounding the steam turbine and/or driven equipment;

b) an enclosure ventilation and purging system;

c) a fire protection system as specified including enclosure isolation devices.

7.11.2 Enclosures shall be weatherproof as described in 7.11.2.1 through 7.11.2.3.

7.11.2.1 The turbine enclosure shall be designed for the degree of weather exposure and for the site and atmospheric conditions specified.

7.11.2.2 Moisture buildup and corrosion on enclosure panel materials shall be minimized. Water or dust leakage through the enclosure panel walls or roof seams is unacceptable.

7.11.2.3 Materials of construction for enclosure panels shall be resistant to moisture, fire, insects, vermin, and oil wicking.

7.11.3 Enclosures shall be designed to permit onsite maintenance. The degree of enclosure disassembly and/or access for maintenance shall be stated in the proposal. Enclosure floor compartment shall have drain connections and piping to facilitate removal of liquids.

7.11.3.1 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 or removable portions are not acceptable.

7.11.3.2 As a minimum, two access doors and/or manways shall be provided for routine maintenance and inspection. The sealing devices used around the perimeter of these access ways shall be designed to withstand normal use without loss of sealing function. Access doors shall have quick egress mechanism.

7.11.3.3 Conduits and fire prevention systems shall not be attached to the underside of the roof or any other panels that are required to be removed for maintenance.

7.11.4 At least one window shall be supplied on each side of the enclosure, located on an access door and opposite each other. Each window shall be wire-reinforced glass. If necessary, to meet noise limitations, the window shall be double pane wire-reinforced glass with a dead air space between panes.

7.11.5 Lighting for general observation shall be provided within the enclosure. Lights shall be operated by three-way switches located at the accessway on each side of the enclosure.

● **7.11.6** The enclosure shall be provided with a fan driven forced ventilation system designed to provide 100 % of the ventilation load in the most severe climatic/load conditions. The purchaser shall specify fan system redundancy requirements and whether positive or negative pressure is required.

7.11.6.1 Ventilation system shall be designed to maintain a safe inside enclosure temperature for personnel access.

7.11.6.2 The ventilation system shall include air filtration and/or silencing equipment as required by the specified operating site climatic or operational conditions.

7.11.6.3 The ventilation system shall be designed to handle all specified site climatic or operational conditions.

● **7.11.6.4** Ventilation flow shall enter and exit the enclosure via port(s). The purchaser shall specify if additional ventilation ducting is required.

7.11.6.5 If cooldown ventilation is required to prevent damage to auxiliary systems, or instrumentation within the enclosure, a UPS-powered fan shall be provided.

7.11.6.6 Ventilation system shall have been proved to ensure that no dead spaces exist within the enclosure either by physical type test or other means to avoid the chance of dangerous accumulations of vapor occurring.

7.11.6.7 All fire suppression devices such as dampers and detection devices used within the enclosure shall be designed to operate throughout the entire range of operational service conditions encountered within the enclosure.

7.11.7 If a sound enclosure is provided over a steam turbine, the turbine vendor shall not provide any sentinel valves or relief valves that have the potential to discharge steam into the enclosure.

● **7.11.8** If specified, an acoustical treatment shall be furnished by the turbine vendor. It shall conform to the maximum allowable SPL specified by the purchaser (see 6.1.9).

7.12 Grounding

7.12.1 Condensing turbines shall be provided with at least two grounding brushes on or near the same end of the shaft.

7.12.1.1 The brushes shall be arranged to allow their replacement with the turbine in operation.

7.12.1.2 The brushes shall be of the size and material suitable for the service. The vendor shall include drawings with the proposal showing the number and location of the brushes.

● **7.12.2** If specified, grounding brush connections shall be mounted inside an enclosure suitable for the hazardous electrical area classification (see 6.1.13).

8 Inspection, Testing, and Preparation for Shipment

8.1 General

● **8.1.1** The purchaser shall specify the extent of participation in the inspection and testing and the amount of advance notification required.

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

NOTE Annex M includes inspector's checklist for guidance.

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

8.1.4 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

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

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

NOTE Hydro and running test notification is covered in 8.3.1.3.

8.1.7 A witnessed mechanical running or performance test requires written confirmation of the successful completion of a preliminary test. Results of the preliminary test shall be provided if requested.

● **8.1.8** The purchaser shall specify if the vendor may perform an unwitnessed mechanical or performance preliminary test prior to a witnessed test.

NOTE Many purchasers prefer not to have preliminary tests prior to witnessed tests to understand any difficulties encountered during testing.

8.1.9 Equipment, materials, and utilities for the specified inspection and tests shall be provided by the vendor.

8.1.10 The purchaser's representative shall have access to the vendor's quality-control program for review.

8.2 Inspection

8.2.1 General

8.2.1.1 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) test data to verify that the requirements of the specification have been met;

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

d) results of quality-control tests and inspections;

e) details of all repairs;

f) final-assembly maintenance and running clearances;

g) other data specified by the purchaser or required by applicable codes and regulations (see 5.2 and O.3.1.1 in Annex O);

h) specifications for all purchased items.

NOTE Annex N includes typical inspection activities for forged or rolled, welded, and cast materials for steam turbine components.

8.2.1.2 Pressure-containing parts shall not be painted until the specified pressure testing of the parts is completed.

NOTE Purchased auxiliaries typically arrive at the packager already tested and painted. The above is not intended for such components if subsequently included in assembly testing.

● **8.2.1.3** In addition to the requirements of 6.11.3.1 and the ASTM material specifications, the purchaser shall identify the following:

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 (see Table 3).

NOTE 1 Inspection of pressure-containing components is covered in 6.4.16.

NOTE 2 ASTM material specifications contain mandated and supplemental inspections.

NOTE 3 Review of quality assurance and testing are usually the items on the coordination meeting agenda.

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

8.2.2 Material Inspection

8.2.2.1 General

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

NOTE The material inspection of pressure-containing parts is covered in 6.4.16.

8.2.2.1.2 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 and developed by the vendor for the specific application.

8.2.2.1.3 Acceptance standards for 8.2.2.2 through 8.2.2.5 shall be as agreed unless other corresponding procedures and acceptance criteria have been specified.

8.2.2.2 Radiography

Radiography shall be in accordance with ASTM E94, ASME Code, and ASME B31.3.

8.2.2.3 Ultrasonic Inspection

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

8.2.2.4 Magnetic Particle Inspection

Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709. To prevent buildup of potential voltage in the equipment, all components shall be demagnetized to the free air gauss levels in Table 5 when measured with a calibrated Hall effect probe.

Table 5—Maximum Allowable Free Air Gauss Levels

Gauss Level	Component
±2 Gauss	Bearing and casing end seal assemblies including all components
±4 Gauss	Turbine casing and all stationary components except bearing and casing end 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.

8.2.2.5 Liquid Penetrant Inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E165 and ASTM E1417.

8.2.2.6 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.

8.2.2.7 A heat stability check shall be performed on turbine shaft or rotor forging in accordance with ASTM A472.

● **8.2.2.8** If specified, details of procedures and acceptance limits for thermal stability tests on turbine rotors shall be supplied.

8.2.2.9 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.

8.2.3 Mechanical Inspection

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

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

● **8.2.3.3** If specified, 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.

● **8.2.3.4** 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.

8.3 Testing

8.3.1 General

8.3.1.1 Equipment shall be tested in accordance with 8.3.2, 8.3.3, 8.3.4, and 8.3.5. Other tests that may be specified by the purchaser are described in 8.3.6.

8.3.1.2 At least 6 weeks before the first scheduled mechanical running test, the vendor shall submit to the purchaser for their review, comment, and approval, the detailed procedures for the mechanical running test and all specified optional tests (see 8.3.6) including acceptance criteria for all monitored parameters.

8.3.1.3 Testing notification requirements are covered in 8.1.6. If the testing is rescheduled, the vendor shall notify the purchaser. A new date shall be agreed with 5 working days advanced notification.

8.3.2 Hydrostatic Test

8.3.2.1 Unless otherwise specified, pressure-containing parts of turbine shall be tested hydrostatically with liquid at a minimum of 1.5 times the maximum allowable working pressure. The minimum hydro test pressure shall not be less than 150 kPa (22 psi).

NOTE ASME BPVC and some European standards allow pressure vessel to be hydrostatically tested at pressure as low as 1.3 times the maximum allowable working pressure.

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

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

8.3.2.1.2 The vendor shall define hydrostatic test procedure for turbines with double shell construction.

8.3.2.2 Casing Hydrostatic Test

8.3.2.2.1 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the maximum allowable temperature.

8.3.2.2.2 Allowable stress values used shall conform to those given in ASME B31.3 for piping or in section 6.2.1.1 for casings. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The datasheets shall list actual hydrostatic test pressures.

NOTE Properties of many grades of steel do not change appreciably at temperatures up to 200 °C (400 °F).

8.3.2.2.3 Where applicable, test shall be in accordance with the code or standard to which the part has been designed. If a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

8.3.2.2.4 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 100 parts per million. To prevent deposition of chlorides on austenitic stainless steel as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

NOTE 1 Chloride content and its concentration is limited to prevent chloride stress corrosion cracking.

NOTE 2 NACE stress corrosion cracking resistance of 304 and 316 at temperatures below 50 °C (122 °F) shows that stress corrosion cracking can be avoided at much higher concentrations than allowed above. This limit is set based on use of potable water and the requirement to wipe dry, which prevents much higher concentration of chlorides from forming.

8.3.2.2.5 Test durations shall be sufficient to permit examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the pressure containing parts or joints is observed for a minimum of 30 minutes. Large, heavy pressure containing parts may require a longer testing period to be agreed by the purchaser and the vendor.

8.3.2.2.6 Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure is acceptable.

NOTE 1 The purpose of the pressure hydro test is to prove pressure casing integrity and not to prove joint sealing.

NOTE 2 Turbine casing joint designs cannot practically accommodate the casing hydrostatic test pressure required for some high temperature steam applications because casing distortion and casing joint leakage can occur. In these cases, use of sealant compound on casing joints is acceptable during the casing hydrostatic test.

8.3.2.3 Casing Joint Leakage Test

8.3.2.3.1 A hydrostatic test for casing joint leakage shall be performed as defined in 8.3.2.1. Temperature corrections as specified in 8.3.2.2.1 are not required for this test.

8.3.2.3.2 This test shall be performed after the casing hydrostatic test. Gaskets shall not be used at the casing joint for this test. Suitable joint sealing compound may be used (see 6.2.4). The test shall be considered satisfactory when neither leaks nor seepage through the casing joint is observed for a minimum of 30 minutes.

8.3.2.3.3 The casing joint leakage test may be combined with the casing hydrostatic test, provided casing joint gaskets are not used.

8.3.3 Mechanical Running Test

8.3.3.1 The requirements of items 8.3.3.1.1 through 8.3.3.1.13 shall be met before the mechanical running test is performed.

8.3.3.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

8.3.3.1.2 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. Oil flow rates for each bearing housing shall be measured.

8.3.3.1.3 Test stand oil filtration shall not exceed 10 microns nominal. Oil system components downstream of the filters shall meet the cleanliness requirements of API 614 before any test is started.

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

8.3.3.1.5 All warning, protective, and control devices used during the test shall be checked, and adjustments shall be made as required.

8.3.3.1.6 Facilities shall be installed to prevent the entrance of oil into the turbine during the mechanical running test. These facilities shall be in operation throughout the test. Entrance of oil into the turbine during the mechanical running test is prohibited.

8.3.3.1.7 Testing shall be performed with contract half coupling. If contract half coupling is not used, the test coupling installed with or without moment simulator (in accordance with API 671), shall not differ from the contract coupling's overhung moment by more than ± 10%.

8.3.3.1.8 All contract vibration probes, cables, oscillator-demodulators, and accelerometers shall be in use during the test.

8.3.3.1.9 If agreed, shop oscillator-demodulators and readouts that meet the accuracy requirements of API 670 shall be used with the contract probes.

8.3.3.1.10 Shop test facilities shall include the capability of continuously monitoring, displaying, recording, and printing vibration displacement and phase, vibration spectrum, Bode plots, shaft orbits, bearing metal temperatures, bearing lube oil inlet pressures, and bearing lube oil inlet and outlet temperatures.

8.3.3.1.11 The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.1.8 through 8.3.3.1.10 shall serve as the basis for acceptance or rejection of the equipment (see 6.8.3).

8.3.3.1.12 If seismic test values are specified, vibration data (minimum and maximum values) shall be recorded and located (clock angle) in a radial plane transverse to each bearing centerline (if possible), using shop instrumentation during the test.

8.3.3.1.13 All instrumentation used for the tests shall have valid calibration at the time of the test.

8.3.3.2 The operation of the control systems furnished with the equipment package shall be demonstrated and the mechanical running test of the steam turbine shall be conducted as specified in 8.3.3.2.1 through 8.3.3.3.

8.3.3.2.1 The equipment shall be operated at speed increments of ~10% of maximum continuous speed from zero to the maximum continuous speed and run at the maximum continuous speed until bearings, lube-oil temperatures, and shaft vibrations have stabilized.

NOTE 1 A typical guideline for bearing metal and lube oil temperature stabilization is not more than 1 °C (2 °F) rise over 15 minutes at constant oil inlet pressure and temperature conditions.

NOTE 2 A typical guideline for vibration stabilization is amplitude change over 15 minutes is less than ± 20 % of the vibration limit at steady-state operating conditions.

NOTE 3 Figure 6 illustrates the mechanical running test including requirements of 8.3.3.2.1 through 8.3.3.2.5.

8.3.3.2.2 The speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 minutes.

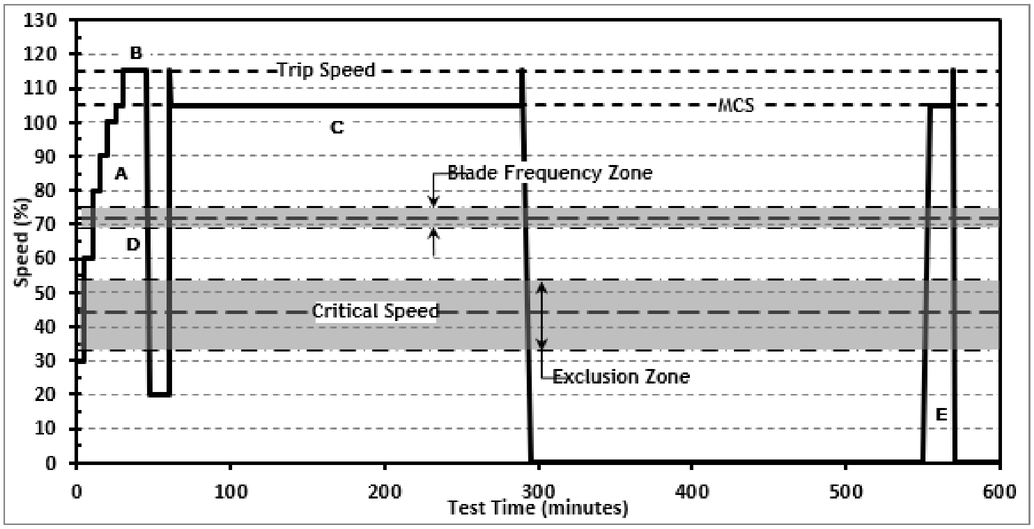
8.3.3.2.3 Overspeed trip devices shall be checked and adjusted until values within 1 % of the nominal trip setting are attained. Mechanical overspeed devices shall attain three consecutive nontrending trip values that meet this criterion.

8.3.3.2.4 The speed governor and any other speed-regulating devices shall be tested for smooth performance over the operating speed range. No-load stability and response to the control signal shall be checked. The sensitivity and linearity of relationship between speed and control signal, and, for adjustable governors, the response speed range shall be recorded.

8.3.3.2.5 The speed shall be reduced to the maximum continuous speed and the equipment shall be run continuously for 4 hours.

NOTE 1 Design steam conditions are usually not possible to be reproduced during mechanical running test as these are limited by the available shop steam inlet and exhaust conditions.

NOTE 2 Reduced steam inlet conditions are typically needed during no-load operation for extended periods of time during the test to prevent overheating of the unit and exceeding design clearances.



Key

A Warm-up Phase
- Speed increased multiple increments
- Avoid critical speeds, turbine blade frequencies, etc.

B Trip Speed Operation
- 15 minutes, followed by vibration data collection during coastdown

C Maximum Continuous Speed Four-hour Test
- Oil supply pressure and temperature variations performed
- Operating conditions recorded

D Shutdown/Ramp Down
- Momentary increase to trip speed
- Transient operation recorded
- Used as baseline for verification testing

E Unbalance Rotor Response Verification Testing

Figure 6—Mechanical Running Test

8.3.3.3 The requirements of 8.3.3.3.1 through 8.3.3.3.8 shall be met during the mechanical running test.

8.3.3.3.1 During the mechanical running test, the mechanical operation of all equipment being tested, and the operation of the test instrumentation, shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 6.8.7.8 and shall be recorded throughout the operating speed range.

8.3.3.3.2 While the equipment is operating at maximum continuous speed and at any other speed 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, these data shall cover a frequency range from 0.05 to 8 times the maximum continuous speed. If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 6.8.7.8, the purchaser and the vendor shall agree on requirements for further investigation which may include additional testing and on the equipment's acceptability.

8.3.3.3.3 The mechanical running test shall verify that lateral critical speeds conform to the requirements of 6.8.2 and 6.8.3. Any noncritically damped critical speed below the trip speed shall be determined during the mechanical running test and stamped on the nameplate followed by the word "test."

● **8.3.3.3.4** Synchronous vibration amplitude and phase angle versus speed for deceleration shall be plotted before and after the 4-hour run. Both the filtered (one per revolution) and the unfiltered vibration levels shall also be plotted. If specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be 400 r/min to the specified turbine overspeed trip speed.

8.3.3.3.5 Shop verification of the unbalanced response analysis shall be performed in accordance with 6.8.3.

● **8.3.3.3.6** If specified, all real-time vibration data as agreed by the purchaser and vendor shall be recorded and a copy provided to the purchaser.

8.3.3.3.7 Lube oil inlet pressure and temperature shall be varied through the operating range including trip values permitted in the turbine operating manual and in accordance with a) through c). The lube oil and control oil temperatures shall be held for at least 30 minutes at a value corresponding to the minimum allowable viscosity and 30 minutes at a value corresponding to maximum allowable viscosity. Under both conditions, shaft vibration shall be measured, checking in particular for oil film instabilities.

a) This shall be done during the 4-hour test.

b) This option does not constitute a waiver of the other specified test requirements.

c) The combination of pressure and temperature variations during the test shall be agreed.

NOTE 1 The extent of reduction in the lube oil inlet pressure depends on the low lube oil pressure alarm set point.

NOTE 2 The maximum allowable lube oil viscosity during shop test is usually limited by supply temperature of the cooling medium.

8.3.3.3.8 If spare rotor is ordered to permit concurrent manufacture, the spare rotor shall also be given a mechanical running test in accordance with the requirements of this standard.

● **8.3.3.3.9** The purchaser shall specify testing requirements for other spare parts.

8.3.3.4 The requirements of 8.3.3.4.1 and 8.3.3.4.2 shall be met after the mechanical running test is completed.

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

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

8.3.4 Factory Overspeed Shutdown (Trip) System Test

The vendor shall verify that the actual response time of the overspeed shutdown (trip) system does not exceed the response time used in the overspeed calculation for the maximum speed excursions. If the vendor does not supply all overspeed shutdown (trip) system components, the response of components not supplied shall be agreed and incorporated in the total response time.

NOTE This test is typically run by manually initiating a trip while the turbine is at maximum continuous speed while recording the response time of the system, i.e. time required for the governor, and trip and throttle valve to close.

8.3.5 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 and hydraulic pressure versus time shall be recorded or if approved by the purchaser, valve closure time based on limit switch signal shall be recorded. The trip time during test shall not exceed the specified trip time.

● 8.3.6 Optional Tests and Inspections

If specified, the shop/field tests described in 8.3.6.1 through 8.3.6.9 shall be performed. Test details shall be agreed by the purchaser and the vendor.

● **8.3.6.1 Performance Test**

The turbine shall be tested in accordance with ASME PTC 6 or IEC 60953. Vibration levels shall be measured and recorded during this test, as specified in 8.3.3.1.11 and 8.3.3.1.12.

● **8.3.6.2 Complete Unit Test**

Such components as turbine, driven equipment, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. The complete-unit test may be performed in place of or in addition to separate tests of individual components specified. If specified, torsional vibration measurements shall be made to verify the vendor’s analysis.

● **8.3.6.3 Auxiliary Equipment Test**

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.

● **8.3.6.4 Post-test Inspection**

The steam turbine shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test.

● **8.3.6.5 Field Overspeed Shutdown (Trip) System Response Test**

After complete field installation, the vendor or the party responsible for conducting this test shall provide the purchaser with the actual measured total overspeed trip system response times for at least four overspeed trip events as proof that the total system response time meets the requirements in 7.7.2.3.4.

NOTE 1 This test is typically run by manually initiating a trip while the turbine is at maximum continuous speed while recording the response time of the system, i.e. time required for the governor, and trip and throttle valve to close.

NOTE 2 Total overspeed trip 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.

● **8.3.6.6 Spare Parts Test**

Spare parts such as couplings, bearings, and seals shall be tested.

NOTE A mechanical running test of spare rotor is mandated in 8.3.3.3.8.

● **8.3.6.7 Inspection of Hub/Shaft Fit for Hydraulically Mounted Couplings**

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.

8.3.6.8 Governor System Response Test Under Load

The response time of speed governing system shall be continuously recorded to confirm compliance with the requirements for maximum speed rise specified in 7.7.2.1.11, Item c).

8.3.6.9 Sound Level Test

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

NOTE 1 This test may not reflect field sound levels due to shop test environment.

NOTE 2 SPLs can be converted into sound power levels in accordance with ISO 10494.

8.4 Preparation for Shipment

8.4.1 Equipment shall be prepared for the type of shipment specified, including blocking of the rotor if necessary. Blocked rotors shall be identified by means of corrosion-resistant tags attached with stainless steel wire.

8.4.1.1 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.

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

8.4.1.3 The vendor's long-term storage package (more than one year) shall be included in the proposal as an alternative.

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

8.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser.

8.4.4 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.

NOTE Austenitic stainless steels are typically not painted.

8.4.5 Exterior machined surfaces, except for corrosion-resistant material, shall be coated with a rust preventative.

8.4.6 The interior of the equipment shall be clean; be free from scale, welding spatter, and foreign objects; and sprayed or flushed with a solvent removable rust preventative. The rust preventative shall be applied through all openings while the rotor is rotated.

8.4.7 Internal surfaces of bearing housings shall be coated with an oil-soluble rust preventative that is compatible with the lubricating oil.

8.4.8 Flanged openings shall be designed per 8.4.8.1 through 8.4.8.4.

8.4.8.1 Flanged openings shall be provided with metal closures at least 5 mm ($^3/_{16}$ in.) thick with elastomer gaskets and at least four bolts that match the ASME standard bolt for the flange size and pressure class.

8.4.8.2 Each elastomeric gasket shall be equal to the flange diameter.

8.4.8.3 For studded openings, all nuts shall be used to secure closures.

8.4.8.4 Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

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

NOTE These are shipping plugs.

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

8.4.11 Lifting points, lifting lugs, and the center of gravity shall be clearly identified on the equipment package. The recommended lifting arrangement shall be as described in the installation manual.

8.4.11.1 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.

8.4.11.2 Larger turbines shall have supports as required by the type of transportation and handling.

8.4.12 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.

8.4.13 A spare turbine rotor shall be prepared and packed according to 8.4.13.1 through 8.4.13.7.

8.4.13.1 If purchased, it shall be prepared for unheated indoor storage for a period of at least 10 years.

8.4.13.2 It shall be treated with rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor.

● **8.4.13.3** The rotor shall be crated for domestic or export shipment as specified.

8.4.13.4 A purchaser-approved resilient material 3 mm ($^1/_8$ in.) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)] shall be used between the rotor and the cradle at the support areas.

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

8.4.13.5 The rotor shall not be supported on journals.

NOTE More than two supports can be needed for long turbine rotors to prevent sagging during horizontal storage.

8.4.13.6 Mark the probe target area barriers with the words “Probe Area—Do Not Cut.”

● **8.4.13.7** If specified, the rotor shall be prepared for vertical storage. It shall be supported from its coupling end with a fixture designed to support minimum 1.5 times the rotor’s weight without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation, and maintenance manual.

● **8.4.14** If specified, spare rotor shall be shipped in a container capable of nitrogen pressurization and designed for long-term vertical or horizontal storage. Rotor shall have rust preventative coating.

NOTE Nitrogen purge pressure in rotor storage container is usually in the range of 35 kPag to 69 kPag (5 psig to 10 psig).

8.4.15 Critical shaft areas such as journals, gland seal areas, probe target areas, and coupling fit areas (for hydraulically fitted coupling hubs) shall be protected with a corrosion barrier followed by a separate barrier material to protect against incidental mechanical damage.

8.4.16 Loose components shall be dipped in wax or placed in plastic bags and contained by wooden boxes. Loose boxes are to be securely blocked in the shipping container.

8.4.17 Spare parts shall be packaged separately from materials belonging to the main order.

8.4.18 All packing materials shall be biologically decomposable or recyclable.

8.4.19 Composition wood product such as particleboard, medium-density fiberboard (MDF), and oriented strand board (OSB) shall not be used.

8.4.20 Each item shall be marked with lifting and sling points that will distribute the load equally and keep them in a stable horizontal position.

8.4.21 Each item shall be provided with lashing points to secure the load horizontally and axially during transport.

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

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

8.4.24 Connections on turbine auxiliary piping, removed for shipment, shall be matchmarked for ease of reassembly.

8.4.25 The fit-up and assembly of turbine mounted piping shall be completed in the vendor's shop prior to shipment.

8.4.26 Wood used in export shipping shall comply with the requirements of ISPM Pub. No. 15-FAO 2018 (published 2019).

8.4.27 Package Markings and Shipping Documentation

8.4.27.1 All markings shall be in English and other specified language.

8.4.27.2 Package markings shall be stenciled on two opposite sides of the shipping unit. A shipping unit may be a box, carton, bundle, crate, drum, or a loose self-supported piece of equipment.

8.4.27.3 Lettering shall be between 7.6 cm and 12.7 cm (3 in. and 5 in.) high in weatherproof black ink to ensure visibility.

8.4.27.4 Shipping packages that cannot be stenciled directly shall have attached corrosion resistant metal tags with raised markings.

8.4.27.5 Shipping packages shall be marked with industry standard cautionary symbols indicating center of gravity, sling or lifting points, top heavy packages, fragile and liquid contents, moisture sensitive contents etc. per ASTM D5445-05.

8.4.27.6 Package markings shall include:

a) purchaser's purchase order number and tag number;

b) shipping unit piece number;

c) gross weight;

d) dimensions;

e) purchaser's project name.

8.4.27.7 Packaged equipment shall be shipped with duplicate packing lists—one inside and the other on the outside of the shipping container. Also, a paper copy of package markings shall be inside each container.

8.4.27.8 One copy of the manufacturer's installation instructions shall be packed and shipped with the turbine.

8.4.27.9 Equipment or materials that contain or are coated with chemical substances shall be prominently tagged at openings to indicate the nature of contents and precautions for shipping, storage, and handling.

NOTE Some examples include oils, corrosion inhibitors, antifreeze solutions, desiccants, hydrocarbon substances, and unused paint.

8.4.27.9.1 Substances that are supplied with the shipment shall have a safety datasheet (SDS).

8.4.27.9.2 If a substance is exempt from regulation, a statement to that effect shall be included.

8.4.27.9.3 At least two weeks before shipment, SDSs shall be forwarded to the receiving facility, to allow planning for handling of any regulated substances.

8.4.27.9.4 SDSs in protective envelopes shall be affixed to the outside of the shipping package.

9 Vendor's Data

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

● **9.2** If specified, the information specified in Annex O shall be provided.

Annex A
(informative)

Typical Datasheets

This annex contains typical datasheets available in PDF format for use by the purchaser and the vendor. The steam turbine datasheets are presented in SI units (Annex A.1) and USC units (Annex A.2). The project design datasheets are presented SI units (Annex A.3) and USC units (Annex A.4). Unless indicated otherwise, all pressure units are gauge pressure.

A.1 Steam Turbine Datasheets in SI Units

	JOB NO. ____ ITEM NO. ____
	PURCHASE ORDER NO. ____
SPECIAL-PURPOSE STEAM TURBINE DATASHEET (API 612 - 8th EDITION) SI UNITS	SPECIFICATION NO. ____
	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 ○ THE PERIOD OF UNINTERRUPTED CONTINUOUS OPERATION (6.1.1): ____
8 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER □ MANUFACTURER ○ PURCHASER OR MANUFACTURER
9 PERFORMANCE

	OPERATING POINTS	SHAFT		EFFICIENCY	INLET			INDUCTION/EXTRACTION			EXHAUST			
10–13	○ □ AS APPLICABLE	POWER kW	SPEED r/min	%	FLOW kg/h	PRESS kPaG	TEMP °C	FLOW kg/h	PRESS kPaG	TEMP °C	PRESS kPaG	TEMP °C	ENTHALPY kJ/kg	MOISTURE % (COND. TURB.)
14	RATED													
15	NORMAL (6.1.4)													
16	MINIMUM													
17	OTHER CONDITION													

18 □ STEAM RATE, kg/kW-h (3.173): ____ NORMAL ____ RATED INDUCTION ○ CONTROLLED ○ UNCONTROLLED
19 □ POTENTIAL MAXIMUM POWER (3.150) EXTRACTION ○ CONTROLLED ○ UNCONTROLLED
20 STEAM CONDITIONS (6.1.4)

			○ INLET	○ EXHAUST	○ EXTRACTION INDUCTION	○ EXTRACTION INDUCTION	○ EXTRACTION INDUCTION
23	FLOW kg/h	MAXIMUM					
24		NORMAL					
25		MINIMUM					
26		OTHER					
27	PRESSURE kPaG	MAXIMUM					
28		NORMAL					
29		MINIMUM					
30		OTHER (M.2.2.4.1)					
31	TEMPERATURE °C (TT)	MAXIMUM					
32		NORMAL					
33		MINIMUM					
34		OTHER					

35 SITE AND UTILITY DATA

36 LOCATION: (6.1.19)
37 ○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR
38 ○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE
39 ○ OTHER: ____
40 ○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D
41 ○ LOW TEMPERATURE ○ CORROSIVE AGENTS
42 ○ ELECTRICAL AREA CLASSIFICATION (6.1.13.2)
43 CLASS ____ GROUP ____ DIVISION ____
44 ZONE ____ GROUP ____ TEMPERATURE RATING: ____
45 ○ OTHER APPLICABLE ELECTRICAL CODES (6.1.13.3): ____
46 SITE DATA:
47 ○ ELEVATION ____ m ○ BAROM. PRESS ____ kPaG
48 ○ WINTER TEMP. ____ °C SUMMER TEMP. ____ °C
49 ○ REL. HUMIDITY ____ % DESIGN WET BULB ____ °C
50 ○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES
51 ○ OTHER ____
52 UTILITY CONDITIONS: (6.1.20)
53 ○ AUXILIARY STEAM: MAX NORM MIN
54 INITIAL PRESS.(kPaG)) ____ ____ ____
55 INITIAL TEMPERATURE, °C (TT) ____ ____ ____
56 EXH. PRESS. (kPaG) ____ ____ ____
57 INST. AIR (kPaG): NORM ____ MIN ____ MAX ____
58 INSTRUMENT AIR DEWPOINT: °C

36 ○ ELECTRIC: DRIVERS HEATING INSTRUMENT/ ALARM / CONTROL SHUTDOWN
39 VOLTS ____ ____ ____ ____
40 PHASE ____ ____ ____ ____
41 HERTZ ____ ____ ____ ____
42 kW AVAILABLE ____ ____ ____ ____
42 ○ COOLING WATER / GLYCOL WATER:
43 INLET TEMPERATURE: ____ °C MAXIMUM RETURN ____ °C
44 PRESS. NORM.: ____ kPaG DESIGN ____ kPaG
46 MINIMUM RETURN PRESSURE: ____ kPaG
47 MAXIMUM ALLOWABLE PRESS. DROP: ____ kPaG
48 WATER SOURCE ____
49 VELOCITY, m/s: MIN ____ MAX ____
50 FOULING FACTOR: ____ W/(m²K)
51 ○ UTILITY CONSUMPTION:
52 COOLING WATER: ____ m³/h INST. AIR ____ m³/h
53 AUX. STM: NORMAL ____ kg/h MAXIMUM ____ kg/h
54 AUX. DRIVERS: ELECTRIC ____ kW STEAM ____ kW
55 HEATER(S): ____ kW OTHER: ____

59 REMARKS: ____
60 ____

SPECIAL-PURPOSE STEAM TURBINE DATASHEET (API 612 - 8th EDITION) SI UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 2 OF 10 BY ______

APPLICABLE SPECIFICATIONS:

API 612, SPECIAL-PURPOSE STEAM TURBINES
○ OTHER ______
○ API RP 691 TECHNOLOGY READINESS LEVEL (6.13) ______
○ VENDOR HAVING UNIT RESPONSIBILITY (3.180) (4.1): ______
○ GOVERNING SPECIFICATION, IF DIFFERENT: ______
○ HIERARCHY OF DOCUMENTS (5.3)

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
MINIMUM ALLOWABLE ______ r/min

☐ LATERAL CRITICAL SPEEDS (DAMPED) (6.8.2)
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)

○ STABILITY TEST TO MEASURE DAMPING RATIO AND TO DETERMINE THE CORR. LOG DECREMENT (6.8.5.2)
○ TRAIN TORSIONAL ANALYSIS : TRANSIENT SHORT CIRCUIT FAULT ANALYSIS FOR STEAM TURBINE GENERATOR TRAIN (6.8.6.8)
○ ALTERNATING TORQUE BY BREAKER RECLOSURE (6.8.6.9)

☐ TORSIONAL CRITICAL SPEEDS (9.6):
FIRST CRITICAL ______ r/min
SECOND CRITICAL ______ r/min
THIRD CRITICAL ______ r/min
FOURTH CRITICAL ______ r/min

○ LATERAL ANALYSIS REPORT REQUIRE (6.8.2.4)
○ INDIVIDUAL BODY ○ TRAIN
○ LATERAL AND TORSIONAL ANALYSIS: DATA TO BE PROVIDED FOR INDEPENDENT AUDIT (6.8.14.2) (6.8.15.2)
○ LATERAL AND TORSIONAL ANALYSIS : ACCESS TO DRG. TO DEV. INDEPENDENT MODLS. DATA TO MADE AVAIL. IN ELECTRONIC FORMAT (6.8.14.3) (6.8.15.3)
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED (6.8.6.1) (6.8.6.2)
○ TRAIN TORSIONAL PERFORMED BY

☐ **CASINGS, NOZZLES & DIAPHRAGMS**

☐ MAWP (3.128)(6.2.2)
INLET SECTION ______ EXH. SECTION ______ (kPaG)
INDUCTION / EXTRACT. SECTION ______ (kPaG)
OTHER ______ (kPaG)
☐ MAX ALLOWABLE TEMP. (3.127)
INLET SECTION ______ °C EXHAUST SECTION ______ °C
INDUCTION / EXTRACTION SECTION ______ °C
○ MINIMUM DESIGN METAL TEMPERATURE ______ °C
○ RELIEF VALVE SETTING: INLET ______ (kPaG) ______ (kPaG)
EXTRACTION ______ (kPaG) OTHER ______ (kPaG)

☐ HYDROTEST PRESSURE (8.3.2)
HP CASING ______ MID CASING ______ (kPaG)
EXHAUST CASING ______ OTHER ______ (kPaG)
○ WELDED NOZZLE RING (6.7.2.1) NOZZLE RING ______ % ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST ☐ WELDED
(6.7.2.2) (6.7.2.2.1 to 6.7.2.2.2) ☐ OTHER ______
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	○ (ANSI/ ASME B16.5, B16.47, EN 1092-1, OTHER) (6.4.9.2)	☐ SIZE	☐ FACING	○ POSTION (6.4.3.2)	☐ FLANGED OR STUDDED (6.4.10)	○ MATING FLG. & GASKET BY VENDOR [(6.4.11)]	☐ 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 [(6.2.10.2)]

☐ **ALLOWABLE FORCES & MOMENTS (ANNEX D)**

	INLET FORCE N	INLET MOMENT N-m	EXHAUST FORCE N	EXHAUST MOMENT N-m	EXTRACT. / INDUCT. FORCE N	EXTRACT. / INDUCT. MOMENT N-m
PARALLEL						
TO SHAFT						
VERTICAL						
HORZ. 90°						

ROTATION:(VIEWED FROM INLET END)

○ CW ○ CCW

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MATERIALS-CASINGS & INTERNALS

☐ HIGH PRESSURE CASING ______	☐ DIAPHRAGM/BLADE CARRIERS ______
☐ MID PRESSURE CASING ______	☐ DIAPHRAGM NOZZLES ______
☐ EXHAUST CASING ______	☐ OTHER ______
☐ STEAM CHEST ______	______
☐ NOZZLE RING ______	______
○ STEAM CONTAMINANTS (6.1.4.3) ______	______
○ STEAM PATH COMPONENTS < HRC 22 (6.7.2.7)	______

ROTATING ELEMENTS (6.6)

SHAFT TYPE:	
☐ INTEGRAL WHEELS ☐ BUILT-UP (6.6.2.2) ☐ COMBINATION	☐ SHAFT ENDS: DIAMETER @ COUPLING ______ mm
☐ DOUBLE EXTENDED	○ STRAIGHT ○ TAPER ______ mm/m
☐ NUMBER OF STAGES ______ BEARING SPAN ______ mm	○ KEYED ○ SINGLE ○ DOUBLE
☐ SHAFT MATERIAL ______	○ HYDRAULIC FIT ○ INTEGRAL FLANGE
BLADES(BUCKETS): ☐ MAX TIP SPEED ______ m/s	○ FIELD BALANCING PROVISIONS REQUIRED (6.6.2.4)
☐ FINAL STAGE BLADE LENGTH ______ mm MAX. ______ mm	☐ 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 (6.7.1)

	INLET	EXHAUST
☐ MAX. SEAL PRESSURE, kPaG		
☐ STEAM LEAKAGE, kg/h		
☐ AIR LEAKAGE, m^3/h (std cond.)		
☐ SHAFT DIA. @ SEAL, mm		
☐ STATIONARY LABY. TYPE		
☐ ROTATING LABY. TYPE		
☐ MATERIAL		
☐		
☐		
☐ ______		

TYPE: ○ LABYRINTH (6.7.1.2) ○ OTHER ______

MATERIAL: ______

INTERSTAGE SEALS (6.7.1.2):

TYPE: ○ LABYRINTH

○ OTHER ______

MATERIAL: ______

REMARKS: ______

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BEARINGS AND BEARING HOUSINGS

RADIAL (6.9.1.1) (6.9.2)

	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 %		
☐ PAD MATERIAL (6.9.2.2)		

☐ BEARING SPAN ______ (mm)

THRUST (6.9.1.1) (6.9.2)

	ACTIVE	INACTIVE
☐ TYPE		
☐ MANUFACTURER		
☐ UNIT LOADING MAX. (MPaG)		
☐ UNIT LOAD ULTIMATE (MPaG)		
☐ NUMBER OF PADS		
☐ AREA (mm²)		
☐ PIVOT: CENTER / OFFSET, %		
☐ PAD BASE MATERIAL (6.9.2.3.11)		

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 (7.7.5.4): ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______
☐ BEARING HOUSING CONSTRUCTION : (6.9.3)
TYPE: ○ SEPARATE ○ INTEGRAL
SPLIT ______ MATERIAL ______
☐ BEARING DEFLECTOR(S) MATERIAL: ______

VIBRATION DETECTORS:

○ TYPE ______ ☐ MODEL ______
○ MANUFACTURER ______
○ NUMBER AT EACH SHAFT BRG ______ TOTAL NUMBER ______
○ 2 ORTHOGONALLY LOACTED RADIAL NON CONTACTING VIB. PROBES MOUNTED NEXT TO THE BEARINGS (6.8.7.4.5)
MONITOR SUPPLIED BY (7.7.5.4) : ______
○ 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 ACCORDING WITH API 670 (6.9.3.5)
KEYPHASOR : STEAM TURBINE GEAR DRIVEN EQUIP.
REMARKS: ______

ELECTRICAL SYSTEM (7.7.6)

○ ELECTRICAL MATERIAL INCL. INSULATION CORROSION RESISTANT AND NONHYGROSCOPIC (7.7.6.6)
○ ELECTRICAL MATERIAL INCL. INSULATION SUITABLE FOR TROICAL LOCATION (7.7.6.6)
○ LOW POINT CONDUIT DRAINS FOR INDOOR INSTALLATION (7.7.6.11)

LUBRICATION AND CONTROL OIL SYSTEM (6.10)

○ LUBRICATION AND CONTROL OIL SYSTEM AS PER API 614 (6.10.2)
REFRENCE SPECIFICATIONS: ______
FURNISHED BY ○ TURBINE MFR ☐ OTHERS
○ SEPARATE FOR TURBINE ONLY
☐ COMMON W/ DRIVEN EQUIPMENT & INCL (6.10.5):
______
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

○ PURCHASER'S PREFERRED OIL GRADE (6.10.5.2) :

OIL REQUIREMENTS:	CTRL OIL	LUBE OIL
☐ NOMINAL FLOW, m³/h		
☐ TRANSIENT FLOW, m³/h		
☐ PRESSURE, kPaG		
☐ TEMPERATURE, °C		
☐ TOT. HEAT REJ, MW		
☐ OIL TYPE, Hydrocarbon/Synthetic		
☐ VISCOSITY, SSU @ 37.8°C		
☐ FILTRATION, µm		
☐ ______		
☐ ______		
☐ ______		

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ACCESSORIES

COUPLINGS AND GUARDS (7.3)(7.4)

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 ______ mm
☐ HUB MASS ______ kg
☐ SPACER LENGTH ______ mm
☐ SPACER MASS ______ kg

☐ VENDOR MOUNT HALF COUPLING(7.3.6)
○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (7.3.5)
LUBRICATION REQUIREMENTS
○ GREASE ○ CONT. OIL LUBE ○ NONE
☐ QUANTITY PER HUB ______ kg OR m^3/h

MOUNTING PLATES (7.6) (7.6.1.1)

BASEPLATES FURNISHED BY: ______
○ UNDER TURBINE ONLY ○ OTHER (7.6.2.1) ______
○ OPEN ○ NON-SKID DECKING (7.6.2.10) ○ DRIP RIM
○ LEVELING PADS ○ SUITABLE FOR OPTICAL ALIGN IN FIELD (7.6.2.5)
○ SINGLE SECTION ○ MULTI-SECTION
○ COLUMN MOUNTING (7.6.2.6)
○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ______
○ COMMERCIAL LIFTING ATTA. FURNISHED WITH MAT. AND LOAD TEST CERT. AND ATTESTED BY INDEPENDENT AGENCY (7.6.2.7.7)
○ MACHINED MOUNTING PADS IN SINGLE PLANE AFTER FABRICATION OF BASEPLATE (7.6.2.16)

SOLEPLATES FURNISHED BY: ______
THICKNESS ______ mm
○ SUBPLATES REQUIRED (7.6.2.14)
○ HOLD-DOWN BOLTS FURNISHED BY ______
○ EPOXY PRIMER VENDOR (7.6.1.7.2)
______
○ ANCHOR BOLTS FURNISHED BY (7.6.1.12): ______
○ MOUNTING PLATE FURNISHED BY (7.6.1.1): ______

GEAR UNIT

FURNISHED BY: ______ ○ REFERENCE API 613 ○ OTHER ______
SEE DATASHEETS ______ ______

CONTROL AND INSTRUMENTATION (7.7)

INSTRUMENTS AND CONTROL PANELS SHALL BE IN ACCORDANCE WITH THE FOLLOWING ATTACHED DATASHEETS:
○ API 614, PAGES ______
○ API 670, PAGES ______
○ PURCHASER'S DATASHEETS ______
INSTRUMENTS AND CONTROLS DESIGNED FOR (7.7.1.2) : ○ INDOOR ○ OUTDOOR INSTALLATION
○ INSTRUMENTATION AND CONTROL DESIGN, CONST., INSTALLATION STD. (7.7.1.3) : ______
TERMINAL BOX PROTECTION LEVEL (7.7.1.6) ○ IP 66 ○ NEMA 4X ○ OTHERS : ______
○ TERMINAL BOX MATERIAL OF CONSTRUCTION (7.7.1.6) : ______
TERMINAL BOX MOUNTING (7.7.3.6) : ○ MOUNTED ON UNIT / BASEPLATE ○ SHIPPED LOOSE : ______
○ PANEL INCLUDES ALL PANEL MOUNTED INSTRUMENTS (7.7.3,1) ○ PURCHASER SPECIFICATION (7.7.3.1) : ______
TERMINAL BOX TAGGING (7.7.3.7) : ○ AS PER VENDOR ○ AS PER PURCHASER STANDARD / SPECIFICATION ______
PANEL LOCATION (7.7.3.1.1) : ○ LOCAL ON BASE OF UNIT ○ OTHERS : ______
○ PANEL MOUNTED INSTRUMENTS (7.7.3.1.2) : ______
○ TOTALLY ENCL. PANEL TO MIN. ELECT. HAZARD, TO PREVENT TAMP. OR TO ALLOW PURG. FOR SAFETY OR CORR. PROTECTION (7.7.3.2.1)

PROTECTIVE DEVICES

	EXHAUST RELIEF VALVE (7.2.2.1) (7.2.2.2) (7.2.1)	EXTRACT./INDUCT. RELIEF VALVE (7.2.2.1)	VACUUM BREAKER (7.7.2.3.12)	NON-RETURN VALVE(S) (7.7.2.3.13 to 7.7.2.3.15)	THERMAL RELIEF VALVE(S) (7.2.1)
MOUNTING LOCATION					
SET RELIEF PRESSURE, kPaG			X	X	
CAPACITY, kg/h STEAM			X		
VALVE MANUFACTURER					
VALVE TYPE					
VALVE SIZE/RATING					
FLANGE FACING (FF, RF)					
FURNISHED BY					
QUANTITY					

REMARKS: ______

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1 ○ TRIP (7.7.2.5.1) ○ TRIP & THROTTLE VALVES (7.7.2.5.1) | ○ DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (7.7.2.5.2)

2 LOCATION: ○ MAIN INLET ○ INDUCTION | ▣ STRAINER: OPENING SIZE ______ (mm/MESH)
3 PROVIDED BY: ○ VENDOR ○ PURCHASER | MATERIAL ______
4 ☐ MANUFACTURER ______ MODEL ______ | ○ TEMPORARY START-UP STRAINER ______ (MESH)
5 ☐ SIZE ______ RATING ______ FACING ______ | MATERIAL ______
6 ☐ SIZE ______ RATING ______ FACING ______ | ☐ STEM MATERIAL ______ HARDNESS ______ HRC
7 ☐ SIZE ______ RATING ______ FACING ______ | ☐ SEAT MATERIAL ______ HARDNESS ______ HRC
8 CONSTRUCTION FEATURES: INLET INDUCT. | ☐ PACKING MATERIAL ______ LEAK-OFF ______ kg/h
9 RESET: ○ MANUAL ○ HYDRAULIC | ☐ SPRING SUPPORT OF VALVE REQUIRED
10 TRIP: ○ LOCAL (MANUAL) ○ REMOTE | ○ BY VENDOR ○ BY PURCHASER
11 EXERCISER: ○ LOCAL (MANUAL) ○ REMOTE
12 ○ FULLY OIL OPERATED

13 **GOVERNOR-CONTROLLED VALVE(S):**

14 LOCATION	MAIN INLET	INDUCTION	INDUCTION	INDUCTION	NOTES
15			EXTRACTION	EXTRACTION	
16 TRIP POSTION (OPEN/CLOSED)					
17 NUMBER OF VALVES					
18 CONNECTION SIZE					
19 RATING					
20 FACING (RF, RTJ, OTHER)					
21 ACTION (CAM,BAR, OTHER)					
22 STEM MATERIAL					
23 STEM MATERIAL HARDNESS, HRC					
24 SEAT MATERIAL					
25 SEAT MATERIAL HARDNESS, HRC					
26 PACKING MATERIAL					
27 PACKING LEAKOFF, kg/h					
28					
29					
30					
31					

32 **TURNING GEAR (7.1)** | **MISCELLANEOUS**
33 ▣ TURNING GEAR REQUIRED (7.1.1) | ○ START-UP ASSISTANCE ______ DAYS
34 ○ FURNISHED BY ______ | ○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S
35 ○ TYPE(7.1.5) ______ SPEED ______ r/min | PIPING AND FOUNDATION DRAWINGS (6.1.18) (7.8.2.3)
36 TORQUE : ______ N-M | ○ VENDOR WITNESS INITIAL ALIGNMENT ((6.1.18 (a), (b),(c))
37 ○ ENGAGEMENT (7.1.2) (7.1.3) (7.1.4): ○ AUTO ○ MANUAL | ▣ "Y" TYPE STRAINER
38 ○ MANUFACTURER ______ MODEL ______ | ▣ WATER WASHING CONNECTIONS
39 ○ MOUNTED BY ______ | ○ STATIC CONDUCTING BRUSHES
40 ○ DRIVER: REFERENCE SPECIFICATION ______ | ○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (7.7.2.3.12)
41 DRIVEN BY: ○ ELECTRIC MOTOR ○ STEAM TURBINE | ○ BOLT THREAD CONFORM TO (6.1.23.1) : ______
41 (7.1.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______ | ○ STEAM PIPING SCOPE (7.8.2.1) : ______
42 ○ OPERATOR STATION (7.1.7) ○ LOCAL ○ REMOTE | ○ PROGRESS REPORTS (3.3.1 in Annex O) INTERVALS ______
43 | ○ ______

44 **INSULATION & JACKETING (7.10)** | **SPECIAL TOOLS (7.9)**
45 ○ BLANKET ○ OTHER ______ | ○ COUPLING RING AND PLUG GAUGE AND LAPPING PER API 671 (7.3.7)
46 ○ JACKETING | ○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
47 ○ CARBON STEEL ○ STAINLESS STEEL | ○ OTHER ______
48 ○ EXTENT ______ | ☐ SPREADER BEAM(S)
49 ______ | ○ ON LOAN
50 ______ | ○ PURCHASE
51

52 **ENCLOSURES (7.11)** | **GROUNDING (7.12)**
53 ○ PROVIDED BY VENDOR (7.11.1) : ○ SAFETY ○ FIRE PROTECTION | ○ GROUDING BRUSH MOUNTED INSIDE AN ENCLOSURE MEETING WITH
54 ○ WEATHERPROFFING | WITH ELECTRICAL AREA CLASSIFICATION (7.12.2)
55 ○ FAN DRIVEN FORCED VENTILATION AND PURGING SYSTEM (7.11.6) | **PART LISTS AND RECOMMENDED SPARES (3.4 in Annex O)**
56 ○ FAN SYSTEM REDUNDANCY (7.11.6) : ______ | ○ SPARE PARTS INTERCHANGEABILITY
57 ○ ADDITIONAL VENTILATION DUCTING (7.11.6.4) | **IOM AND TECHNICAL DATA MANUAL (3.5 in Annex O)**
58 ○ ACOUSTICAL TREATMENT (7.11.8) ○ YES ○ NO | ○ DRAFT MANUAL SUBMISSION BEFORE TEST (3.5.1.3 in Annex O)
59 ○ MAXIMUM ALLOWABLE SPL (7.11.8) : ______ DBA | ○ TECHNICAL DATA MANUAL AT SHIPMENT (3.5.4 in Annex O)
60
61

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GOVERNOR (7.7.2.1)	
TYPE ○ DIGITAL PROCESSOR BASED	○ MANUFACTURER ______ MODEL ______
○ OTHER ______	○ SUPPLIED BY (7.7.5.4): ______
○ SIMPLEX ○ DUPLEX ○ TMR	○ CONTROL MODES (7.7.2.1.21) ○ SINGLE CONTROL EXT./IND.
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 TYPE	
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
○ UNUSUAL CONDITIONS ○ REVERSE ROTATION POSSIBLE	○ AUTOMATIC VOLTAGE REGULATION
(6.1.4.2) (6.9.1.4) AFTER TURBINE TRIP	○ TURBINE INLET PRESSURE LIMITING
○ OTHER ______	○ 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 (7.7.2.1.22)
○ OVERSPEED TEST ENABLE	○ INDUCTION CONTROL ENABLEI (7.7.2.1.22)
○ 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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GOVERNOR INSTALLATION REQUIREMENTS

LOCATION
- ○ LOCAL (AT TURBINE)
- ○ REMOTE (CONTROL ROOM)
- ○ OTHER ______
- ○ AREA CLASSIFICATION:
  CLASS ___ GROUP ___ DIVISION ______
  ZONE ___ GROUP ___ TEMP. RATING: ______

ENCLOSURE
- ○ IP65
- ○ NEMA 4
- ○ NEMA 4X
- ○ OTHER ______

MOUNTING ○ FLUSH MOUNT IN PANEL ○ SURFACE MOUNT
○ VERTICAL RACK

POWER SOURCE	SINGLE	DUAL
120 V (a.c.)	○	○
220 V (a.c.)	○	○
125 V (d.c.)	○	○
24 V (d.c.)	○	○
______	○	○
______	○	○

LOCAL GOVERNOR CONTROL PANEL ○ REQUIRED ○ NOT REQUIRED

LOCATION
- ○ LOCAL (AT TURBINE)
- ○ REMOTE CONTROL ROOM
- ○ OTHER ______

ENCLOSURE
- ○ IP65
- ○ NEMA 4 ○ NEMA 4X
- ○ OTHER ______ ___
- ○ AREA CLASSIFICATION: ______
  CLASS ___ GROUP ___ DIVISION ______
  ZONE ___ GROUP ___ TEMP. RATING: ______

OUTPUTS FROM PANEL TO GOVERNOR
- ○ START
- ○ TRIP
- ○ RAISE
- ○ LOWER
- ○ OVERSPEED TEST
- ○ RAMP TO MINIMUM CONTINUOUS
- ○ REMOTE SET POINT ENABLE/DISABLE
- ○ RESET
- ○ OTHER ______

INPUTS TO PANEL FROM GOVERNOR
- ○ COMMON ALARM TRIP
- ○ TRIP LAMP
- ○ REMOTE SET POINT ENABLED LAMP
- ○ SPEED SET POINT METER
- ○ SPEED
- ○ OTHER ______

MISCELLANEOUS GOVERNOR DETAILS

GOVERNOR ACTION ON LOSS OF REMOTE SIGNAL:
- ○ LOCKS ON LAST VALUE
- ○ GOES TO MINIMUM CONTINUOUS
- ○ GOES TO MAXIMUM CONTINUOUS

EXTERNAL INTERFACE DEVICE TYPE: ○ PRINTER ○ CRT ○ MODEM

FORMAT: ○ GRAPHIC DISPLAY ○ TABULAR DATA ○ TRENDING (REAL TIME) ○ HISTORICAL ARCHIVING

○ DISTRIBUTIVE CONTROL SYSTEM MANUFACTURER ______ ○ MODEL ______

DATA TRANSMISSION ○ DATA LINK ○ DISCRETE I/O ○ NETWORK TYPE ______ ○ PROTOCOL ______

GOVERNOR SPEED PICKUP SENSORS (7.7.2.1.13 to 7.7.2.1.15):
MANUFACTURER ______ MODEL ______ INSTALLATION: ○ DUAL ○ TRIPLE ○ INSTALLED SPARE
○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______

ACTUATOR(S): ○ SUPPLIED BY ______ ○ MANUFACTURER ______ ○ MODEL ______
ACTUATOR TYPE ○ HYDRAULIC ○ PNEUMATIC ○ SINGLE COIL ○ MULTI COIL ○ OTHER ______

TURBINE MOUNTED ACCESSORIES

TACHOMETER ○ MANUFACTURER ______ ○ MODEL ______ ○ NUMBER REQUIRED. ______
○ LOCATION(S) ______

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Line		
1	**TURBINE OVERSPEED SHUTDOWN (TRIP) SYSTEM (7.7.2.3)**	
2	○ FURNISHED BY (7.7.5.4): ______	○ 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 (7.7.2.4.4) ○ 2 OUT OF 4 VOTING LOGIC (7.7.2.4.4)	○ NORMALLY CLOSED
7	○ ACCELERATION TRIP (7.7.2.2.3)	○ VOLTAGE LEVEL: ______
8	○ DESIGN CONFIRM TO IEC 6150 / IEC 61511 (7.7.2.3.7)	______
9	○ OTHER ______	
10	______	
11	**GLAND SEALING AND VACUUM SYSTEM (7.5)**	
12	SYSTEM PER: ○ ANNEX F.1 ○ ANNEX F.2	○ VACUUM SYSTEM FURNISHED BY ______
13	○ OTHER ______	○ SHIP LOOSE ○ SKID MOUNTED
14	○ AVAIL. HEADER PRESSURE ______ kPaG TEMPERATURE ______ °C	○ OTHER ______
15	○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ kPaG	○ GLAND CONDENSOR, SEE SPECIFICATION ______
16	○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE ______ °C	○ STEAM EJECTOR ☐ STEAM PRESS. ______ kPaG
17	☐ SEAL. STM. PRESS. ______ kPaG ☐ FLOW ______ kg/h	☐ STEAM FLOW ______ kg/h
18	☐ SEALING STEAM RELIEF VALVE SET PRESSURE ______ kPaG	○ VACUUM PUMP (7.5.4), SEE SPECIFICATION ______
19	○ FURNISHED BY ______	○ CONDENSATE RECEIVER
20	☐ FLOW ADJUSTING VALVES, TYPE ______	○ LOOP SEAL HEIGHT ______ m
21	○ FURNISHED BY ______	
22	**INSPECTION AND TESTING (8.1) (8.2)(8.3)**	

Line	GENERAL		MECHANICAL RUNNING TEST (8.3.3)	OBSVD	WIT
24	○ SHOP INSPECTION (8.1.5)				
25	○ EXT. OF PART. IN INSP. TEST AND (8.1.1) (8.1.5): ______		○ CONTRACT ROTOR	○	○
26	○ AMOUNT OF ADVANCE INSPECTION NOTIFICATION (8.1.1): ______ WORKING DAYS		○ SPARE ROTOR (8.3.3.3.8)	○	○
27	COMP. OF INSPECTOR'S CHECKLST (ANNEX M) (8.1.2) ○ VENDOR ○ PURCHASER ○ BOTH		○ TEST W/JOB COUPLING	○	○
28	○ SUBMISSION OF PROPOSED CONNECTION DESIGNS FOR APPROVAL BEFORE FAB.BEGINS (6.11.3.5.1)		○ TEST TAPE RECORD REQUIRED	○	○
29	○ UNWITNSSED MECHANICAL / PERFORMANCE PRELIMINARY TEST PRIOR TO WITNESSED TEST (8.1.8)		○ TEST TAPE GIVEN TO PURCH.	○	○
30	**INSPECTION AND MATERIAL TESTING**		○ TEST W/JOB LUBE OIL CONSOLE	○	○
31	○ FINAL ASSEMBLY RECORDS REQUIRED (8.2.1.1 f)		○ SYN. VIB. AMP. AND PHASE ANGLE VS SPEED		
32	○ SUB.OF DETAIL PROC. AND ACCEP. LIMITS FOR THERMAL STABILITY TESTS ON TURBINE ROTOR (8.2.2.8)		DECELE. PLOT IN POLAR FORM (8.3.3.3.4)		
33	○ SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS (6.4.16.2) (6.11.3.4.5) (8.2.1.3) (8.2.2.1.1)		○ REAL TIME VIB. DATA (8.3.3.3.6)		
34			○ ______	○	○
35			○ ______	○	○
36			○ ______	○	○

Line	COMPONENT	MAG PART	LIQ PEN	R.T.	U.T.	PMI (6.11.1.11.2) (6.11.1.11.3)	OBSVD	WIT
37	TRIP & T & T							
38	VALVE	○	○	○	○	○	○	○
39	STEAM CHEST	○	○	○	○	○	○	○
40	CASING	○	○	○	○	○	○	○
41	PIPING	○	○	○	○	○	○	○
42	ROTOR	○	○	○	○	○	○	○
43	SHAFT SLEEVE	○	○	○	○	○	○	○
44	BLADES/SHROUDS	○	○	○	○	○	○	○
45	NOZZLES / BUCKETS	○	○	○	○	○	○	○
46	LOCKING PINS	○	○	○	○	○	○	○
47	DIAPHRAGMS	○	○	○	○	○	○	○
48	PRESSURE PART BOLTS	○	○	○	○	○	○	○
49								

Line		OBSVD	WIT
50	○ HEAT STABILITY (8.2.2.7)	○	○
51	○ CLEANLINESS (8.2.3.3)	○	○
52	○ HARDNESS (8.2.3.4))	○	○
53	○ CASING HYDROSTATIC TEST (8.3.2)	○	○
54	○ BLADE SHAKER TEST (STATIC) (6.6.3.1)	○	○
55	○ FACTORY OVERSPEED SHUTDOWN (TRIP) SYSTEM TEST (8.3.4)	○	○
56	ROTOR BALANCE ○ STANDARD (6.8.7.1)(6.8.7.2)	○	○
57	ROTOR BALANCE ○ OPERATING SPEED (6.8.7.3)	○	○
58	○ LOW SPEED PRIOR TO HIGH SPEED (6.8.7.4.8)	○	○
59	○ LOW SPEED RESIDUAL UNBALANCE CHECK (6.8.7.7)	○	○
60	○ UNBALANCE CHECK AT OPERATING SPEED (6.8.3.2)	○	○
61	○ FINAL SURFACE INSPECTION (8.4.5 TO 8.4.12)	○	○
62	○ EQUIPMENT INSPECTION (8.4.1)	○	○
63	○ ROTOR CRATED (8.4.13.3) ○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT		
64	○ SPARE ROTOR FIT	○	○
65	○ CASING JOINT LEAK TEST (8.3.2.2)	○	○
66	○ ______	○	○

OPTIONAL TESTS AND INSPECTIONS (8.3.6)	OBSVD	WIT
○ PERFORMANCE TEST (8.3.6.1)	○	○
○ COMPLETE UNIT TEST (8.3.6.2	○	○
○ AUXILIARY EQUIPMENT TEST (8.3.6.3)	○	○
○ CONTROL SYSYEMS	○	○
○ LUBE OIL / DRY GAS SYSTEM	○	○
○ TRIP/TRIP & THROTTLE VALVE TEST (8.3.5)	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ POST-TEST INSPECTION (8.3.6.4)	○	○
○ COUPLING TO SHAFT FIT (API 671) (8.3.6.7)	○	○
○ TURNING GEAR	○	○
○ FIELD OVERSPEED SHUTDOWN (TRIP) SYS. RES. TEST (8.3.6.5)	○	○
○ GOVERNOR RESPONSE (8.3.6.8)	○	○
○ SOUND (8.3.6.9)	○	○
○ SPARE PARTS TESTS (8.3.3.3.9) (8.3.6.6)	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○

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ALARMS AND SHUTDOWNS (7.7.5)

ALARMS (7.7.5.2)

○ 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 (COND.TURBINE) ○ GOVERNOR FAULT
○ TURBINE SHUTDOWN SYSTEM RESPONSE TIME SLOWER THAN THE RESPONSE TIME AS TESTED DURING INSNTALLATION
○ TURBINE SHUTDOWN SYSTEM TRIP OIL HEADER SOLENOID RESPONSE TIME SLOWER THAN THE RESPONSE TIME SPEC. BY SOLENOID VENDOR
○ TURBING GEAR FAIL TO ENGAGE WHEN SHUTDOWN (IF APPLICABLE)
○ ______ ○ ______ ○ ______
○ ______ ○ ______ ○ ______

SHUTDOWNS (7.7.5.2)

○ OVERSPEED DETECTED BY GOVERNOR ○ FAILURE OF ALL GOVERNOR SPEED SENSORS ○ LOW-LOW LUBE OIL PRESSURE
○ HIGH HIGH RADIAL VIBRATION (IF SPEC.) ○ HIGH HIGH AXIAL DISPLACEMENT ○ HIGH HIGH BEARING TEMPERATURE (IF SPEC.)
○ ______ ○ ______ ○ ______
○ ______ ○ ______ ○ ______

AUTOMATED SHUTDOWN (TRIP) (7.7.5.2)

○ OVERSPEED DETECTED BY TURBINE SHUTDOWN SYSTEM (SEE 7.7.2.3)
○ ______ ○ ______

ALARM INTIATOR (7.7.5.5.2) ○ AUDIBLE WARNING ○ FLASHING LIGHT ○ BOTH ☐ PARAMETER INTIATE ALARM : ______
SHUTDOWN INT. (7.7.5.5.3): ○ AUDIBLE WARNING ○ FLASHING LIGHT ○ BOTH ☐ PARAMETER INT. SHUTDOWN : ______
○ FIRST OUT ANNUNCIATOR (7.7.5.6) : INDICATE PARAMETER FIRST REACHED ALARAM / SHUTDOWN : ______
○ SEPARATE ANNUNCIATOR (7.7.5.6)
○ EVENT RECORDER TO RECORD THE ORDER OF OCCURRENCE OF ALARMS AND SHUTDOWN (7.7.5.7)
○ CAR SEAL OPEN DEVICE FOR SHUTDOWN SENSING DEVICES (7.7.5.9)

MISCELLANEOUS

PAINTING

○ MANUFACTURER'S STANDARD
○ OTHER ______
○ ______

UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI

SHIPMENT [(8.4.1)(8.4.13)]

○ DOMESTIC ○ EXPORT
○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS
○ WATERPROOF BOXING REQUIRED
○ SPARE ROTOR ASSEMBLY PACKAGED FOR (8.4.13.7):
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ SPARE ROTOR ASSEMBLY SHIPPED IN CONTAINER OF NITROGEN PRESSURIZED FOR LONG TERM STORAGE (8.4.14)

WEIGHTS:

☐ TURBINE ______ kg
☐ ROTOR ______ kg
☐ TURBINE UPPER HALF CASING ______ kg
☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ______ kg
☐ TRIP / TRIP & THROTTLE VALVE ______ kg
☐ MISCELLANEOUS ______ kg
☐ TOTAL SHIPPING MASS ______ kg

PACKGE MARKING AND SHIPPING DOCUMENTATION (8.4.27)

ALL MARKING SHALL BE IN (8.4.27.1)
○ ENGLISH ○ OTHER LANG.: ______

CASING APPURTENANCES (6.3)

○ CASING CONNECTIONS WITH VALVESS FOR INERT GAS BLANKET FOR PRESERVATION OF TURBINE AT SITE BEFORE INSTALLATION (6.3.3)
○ OTHER
______
______

☐ **OTHER CONNECTIONS**

	NO.	SIZE	TYPE
LUBE OIL INLET			
LUBE OIL OUTLET			
FIRST STAGE PRESSURE			
STEAM BALANCE PORT			
CASING DRAIN			

SPACE REQUIREMENTS:

☐ COMPLETE UNIT: L ______ mm W ______ mm H ______ mm
☐ CONTROL PANEL: L ______ mm W ______ mm H ______ mm
☐ OTHER: L ______ mm W ______ mm H ______ mm
☐ OTHER: L ______ mm W ______ mm H ______ mm

VENDOR DRAWING & DATA REQUIREMENTS (9)

○ ANNEX G ○ ANNEX O (9.1.2)
○ DOCUMENTATION TO DEMONSTRATE FIELD PROVEN EQUIPMENT (6.13.1)
○ OTHER ______
______

REMARKS AND ADDITIONAL REQUIREMENTS:

A.2 Steam Turbine Datasheets in USC Units

	JOB NO. ______ ITEM NO. ______
	PURCHASE ORDER NO. ______
	SPECIFICATION NO. ______
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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 ▢ THE PERIOD OF UNINTERRUPTED CONTINUOUS OPERATION (6.1.1) : ______
8 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ▢ PURCHASER OR MANUFACTURER
9 **PERFORMANCE**

	OPERATING POINTS	SHAFT		EFFICIENCY	INLET			INDUCTION/EXTRACTION			EXHAUST				
10–13	○ ☐ AS APPLICABLE	POWER hp	SPEED r/min	%	FLOW lb/h	PRESS psig	TEMP °F	FLOW lb/h	PRESS psig	TEMP °F	PRESS psig / in. HgA	TEMP °F	ENTHALPY Btu/lb	MOISTURE % (COND. TURB.)
14	RATED													
15	NORMAL (6.1.4)													
16	MINIMUM													
17	OTHER CONDITION													

18 ☐ STEAM RATE, lb/hp-h (3.1.73): ______ NORMAL ______ RATED | INDUCTION ○ CONTROLLED ○ UNCONTROLLED
19 ☐ POTENTIAL MAXIMUM POWER (3.1.50) | EXTRACTION ○ CONTROLLED ○ UNCONTROLLED
20 **STEAM CONDITIONS (6.1.4)**

			▢ INLET	▢ EXHAUST	▢ EXTRACTION / INDUCTION	▢ EXTRACTION / INDUCTION	▢ EXTRACTION / INDUCTION
21–22							
23	FLOW lb/h	MAXIMUM					
24		NORMAL					
25		MINIMUM					
26		OTHER					
27	PRESSURE psig	MAXIMUM					
28		NORMAL					
29		MINIMUM					
30		OTHER (M.2.2.4.1)					
31	TEMPERATURE °F (TT)	MAXIMUM					
32		NORMAL					
33		MINIMUM					
34		OTHER					

35 **SITE AND UTILITY DATA**

36 **LOCATION: (6.1.19)** | ○ **ELECTRIC:** DRIVERS HEATING INSTRUMENT/CONTROL ALARM/SHUTDOWN
37 ○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR
38 ○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE | VOLTS ______
39 ○ OTHER: ______ | PHASE ______
40 ○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D | HERTZ ______
41 ○ LOW TEMPERATURE ○ CORROSIVE AGENTS | kW AVAILABLE ______
42 ○ ELECTRICAL AREA CLASSIFICATION: (6.1.13.2) | ○ **COOLING WATER / GLYCOL WATER:**
43 CLASS ___ GROUP ___ DIVISION ______ | INLET TEMPERATURE: ___ °F MAXIMUM RETURN ___ °F
44 ZONE ___ GROUP ___ TEMPERATURE RATING: ______ | PRESS. NORM.: ______ psig DESIGN ______ psig
45 ○ OTHER APPLICABLE ELECTRICAL CODES (6.1.13.3) : ______
46 **SITE DATA:** | MINIMUM RETURN PRESSURE: ______ psig
47 ○ ELEVATION ______ ft ○ BAROM. PRESS ______ psia / HgA | MAXIMUM ALLOWABLE PRESS. DROP: ______ psi
48 ○ WINTER TEMP. ______ °F SUMMER TEMP. ______ °F | WATER SOURCE ______
49 ○ REL. HUMIDITY ______ % DESIGN WET BULB ______ °F | VELOCITY, m/s: MIN ______ MAX ______
50 ○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES | FOULING FACTOR: ______ h-ft²/Btu
51 ○ OTHER ______ | ○ **UTILITY CONSUMPTION:**
52 **UTILITY CONDITIONS: (6.1.20)** | COOLING WATER: ______ GPM INST. AIR ______ SCFM
53 ○ AUXILIARY STEAM: MAX NORM MIN | AUX. STM: NORMAL ______ lb/h MAXIMUM ______ lb/h
54 INITIAL PRESS.(psig) ______ ______ ______ | AUX. DRIVERS: ELECTRIC ______ hp STEAM ______ hp
55 INITIAL TEMPERATURE, °F (TT) ______ ______ ______ | HEATER(S): ______ hp OTHER: ______
56 EXH. PRESS. (psig) ______ ______ ______ | ______
57 INST. AIR (psig): NORM ___ MIN ___ MAX ___ | ______
58 INSTRUMENT AIR DEW POINT: °F
59 REMARKS: ______
60 ______

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APPLICABLE SPECIFICATIONS:
API 612, SPECIAL-PURPOSE STEAM TURBINES
○ OTHER ______
○ API RP 691 TECHNOLOGY READINESS LEVEL (6.1.3) ______
○ VENDOR HAVING UNIT RESPONSIBILITY(3.1.80) (4.1):
______
○ GOVERNING SPECIFICATION, IF DIFFERENT:
______
○ HIERARCHY OF DOCUMENTS (5.3)

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
MINIMUM ALLOWABLE ______ r/min
☐ LATERAL CRITICAL SPEEDS (DAMPED)(6.8.2)
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)

○ STABILITY TEST TO MEASURE DAMPING RATIO AND TO DETERMINE THE CORR. LOG DECREMENT (6.8.5.2)
○ TRAIN TORSIONAL ANALYSIS : TRANSIENT SHORT CIRCUIT FAULT ANALYSIS FOR STEAM TURBINE GENERATOR TRAIN (6.8.6.8)
○ ALTERNATING TORQUE BY BREAKER RECLOSURE (6.8.6.9)

☐ 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 (6.8.2.4)
○ INDIVIDUAL BODY ○ TRAIN
○ LATERAL AND TORSIONAL ANALYSIS: DATA TO BE PROVIDED FOR INDEPENDENT AUDIT (6.8.1.4.2) (6.8.1.5.2)
○ LATERAL AND TORSIONAL ANALYSIS : ACCESS TO DRG. TO DEV. INDEPENDENT MODLS. DATA TO MADE AVAIL. IN ELECTRONIC FORMAT (6.8.1.4.3) (6.8.1.5.3)
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED (6.8.6.1) (6.8.6.2)
☐ TRAIN TORSIONAL PERFORMED BY

☐ **CASINGS, NOZZLES & DIAPHRAGMS**

☐ MAWP (3.1.28)(6.2.2)
INLET SECTION ______ EXH. SECTION ______ (psig)
INDUCTION / EXTRACT. SECTION ______ (psig)
OTHER ______ (psig)
☐ MAX ALLOWABLE TEMP. (3.1.27)
INLET SECTION ______ °C EXHAUST SECTION ______ °F
INDUCTION / EXTRACTION SECTION ______ °F
○ MINIMUM DESIGN METAL TEMPERATURE ______ °F
○ RELIEF VALVE SETTING: INLET ______ (psig) ______ (psig)
EXTRACTION ______ (psig) OTHER ______ (psig)

☐ HYDRO TEST PRESSURE (8.3.2)
HP CASING ______ MID CASING ______ (psig)
EXHAUSTCASING ______ OTHER ______ (psig)
○ WELDED NOZZLE RING (6.7.2.1) NOZZLE RING ______ %ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST ☐ WELDED
(6.7.2.2) (6.7.2.2.1 to 6.7.2.2.2) ☐ OTHER ______
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	○ (ANSI/ ASME B16.5, B 16.47, EN 1092-1, OTHER) (6.4.9.2) (6.4.9.4)	☐ SIZE	☐ FACING	○ POSTION (6.4.3.2)	☐ FLANGED OR STUDDED (6.4.10)	○ MATING FLG. & GASKET BY VENDOR [(6.4.11)]	☐ 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 [(6.2.10.2)]

☐ **ALLOWABLE FORCES & MOMENTS (ANNEX D)**

	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

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1 **MATERIALS-CASINGS & INTERNALS**

Left	Right
2 ☐ HIGH PRESSURE CASING ______	☐ DIAPHRAGM/BLADE CARRIERS ______
3 ☐ MID PRESSURE CASING ______	☐ DIAPHRAGM NOZZLES ______
4 ☐ EXHAUST CASING ______	☐ OTHER ______
5 ☐ STEAM CHEST ______	______
6 ☐ NOZZLE RING ______	______
7 ○ STEAM CONTAMINANTS (6.1.4.3) ______	______
8 ○ STEAM PATH COMPONENTS < HRC 22 (6.7.2.7)	______
9	

10 **ROTATING ELEMENTS (6.6)**

Left	Right
11 SHAFT TYPE:	
12 ☐ INTEGRAL WHEELS ☐ BUILT-UP (6.6.2.2) ☐ COMBINATION	☐ SHAFT ENDS: DIAMETER @ COUPLING ______ in
13 ☐ DOUBLE EXTENDED	○ STRAIGHT ○ TAPER ______ in/ft
14 ☐ NUMBER OF STAGES ______ BEARING SPAN ______ in	○ KEYED ○ SINGLE ○ DOUBLE
15 ☐ SHAFT MATERIAL ______	○ HYDRAULIC FIT ○ INTEGRAL FLANGE
16 BLADES(BUCKETS): ☐ MAX TIP SPEED ______ ft/min	○ FIELD BALANCING PROVISIONS REQUIRED (6.6.2.4)
17 ☐ FINAL STAGE BLADE LENGTH ______ in MAX. ______ in	☐ DESCRIPTION OF FIELD BALANCING PROVISIONS: ______
18 ______	______
19 ______	REMARKS: ______
20 ______	______
21	

22	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE
23 ☐ WHEEL MATERIAL							
24 ☐ BLADE MATERIAL							
25 ☐ BLADE ROOT TYPE							
26 ☐ CLOSURE PIECE TYPE							
27 ☐ TIE WIRE MATERIAL							
28 ☐ SHROUD MATERIAL							
29 ☐ SHROUD ATTACH.							
30 ☐ PITCH DIAMETER, in							
31 ☐ BLADE HEIGHT, in							
32 ☐ BLADE TYPE							
33 ☐ ______							
34 ☐ ______							

35 **SHAFT SEALS (6.7.1)**

36	INLET	EXHAUST
37 ☐ MAX. SEAL PRESSURE, psig		
38 ☐ STEAM LEAKAGE, lb/h		
39 ☐ AIR LEAKAGE, SCFM (std cond.)		
40 ☐ SHAFT DIA. @ SEAL, in		
41 ☐ STATIONARY LABY. TYPE		
42 ☐ ROTATING LABY. TYPE		
43 ☐ MATERIAL		
44 ☐		
45 ☐		
46 ☐ ______		
47		

TYPE: ○ LABYRINTH (6.7.1.2) ○ OTHER ______

MATERIAL: ______

______

______

INTERSTAGE SEALS (6.7.1.2):

TYPE: ○ LABYRINTH

○ OTHER ______

MATERIAL: ______

______

48 REMARKS: ______

49 ______

50 ______

51

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BEARINGS AND BEARING HOUSINGS

RADIAL (6.9.1.1) (6.9.2)

	INLET	EXHAUST
☐ TYPE		
☐ MANUFACTURER		
☐ LENGTH (in.)		
☐ SHAFT DIAMETER (in.)		
☐ UNIT LOAD (ACT/ALLOW), (psig)		
☐ BASE MATERIAL		
☐ BABBIT THICKNESS (in.)		
☐ NUMBER OF PADS		
☐ LOAD: BETWEEN/ON PAD		
☐ PIVOT: CENTER/OFFSET %		
☐ PAD MATERIAL (6.9.2.2)		

☐ BEARING SPAN ________ (in.)

THRUST (6.9.1.1) (6.9.2)

	ACTIVE	INACTIVE
☐ TYPE		
☐ MANUFACTURER		
☐ UNIT LOADING MAX. (psig)		
☐ UNIT LOAD ULTIMATE (psig)		
☐ NUMBER OF PADS		
☐ AREA (in²)		
☐ PIVOT: CENTER / OFFSET, %		
☐ PAD BASE MATERIAL (6.9.2.3.11)		

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 (7.7.5.4): ____
○ LOCATION ____ ENCLOSURE ____
○ MFR. ____ ☐ MODEL ____
☐ BEARING HOUSING CONSTRUCTION : (6.9.3)
TYPE: ○ SEPARATE ○ INTEGRAL
SPLIT ____ MATERIAL ____
☐ BEARING DEFLECTOR(S) MATERIAL: ____

VIBRATION DETECTORS:

○ TYPE ____ ☐ MODEL ____
○ MANUFACTURER ____
○ NUMBER AT EACH SHAFT BRG ____ TOTAL NUMBER ____
○ 2 ORTHOGONALLY LOACTED RADIAL NON CONTACTING VIB. PROBES MOUNTED NEXT TO THE BEARINGS (6.8.7.4.5)
MONITOR SUPPLIED BY (7.7.5.4) : ____
○ 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 ACCORDING WITH API 670 (6.9.3.5)
KEYPHASOR : STEAM TURBINE GEAR DRIVEN EQUIP.
REMARKS: ____

ELECTRICAL SYSTEM (7.7.6)

○ ELECTRICAL MATERIAL INCL. INSULATION CORROSION RESISTANT AND NONHYGROSCOPIC (7.7.6.6)
○ ELECTRICAL MATERIAL INCL. INSULATION SUITABLE FOR TROICAL LOCATION (7.7.6.6)
○ LOW POINT CONDUIT DRAINS FOR INDOOR INSTALLATION (7.7.6.11)

LUBRICATION AND CONTROL OIL SYSTEM (6.10)

○ LUBRICATION AND CONTROL OIL SYSTEM AS PER API 614 (6.10.2)
REFRENCE SPECIFICATIONS: ____
FURNISHED BY ○ TURBINE MFR ☐ OTHERS
○ SEPARATE FOR TURBINE ONLY
☐ COMMON W/ DRIVEN EQUIPMENT & INCL (6.10.5): ____
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

○ PURCHASER'S PREFERRED OIL GRADE (6.10.5.2) :

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 (7.3)(7.4)

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
☐ HUB MASS ______ lb
☐ SPACER LENGTH ______ in
☐ SPACER MASS ______ lb

▢ VENDOR MOUNT HALF COUPLING(7.3.6)
○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (7.3.5)
LUBRICATION REQUIREMENTS
○ GREASE ○ CONT. OIL LUBE ○ NONE
☐ QUANTITY PER HUB ______ lb OR U.S. gal/min

MOUNTING PLATES (7.6) (7.6.1.1)

BASEPLATES FURNISHED BY: ______
○ UNDER TURBINE ONLY ○ OTHER (7.6.2.1) ______
○ OPEN ○ NON-SKID DECKING (7.6.2.10) ○ DRIP RIM
○ LEVELING PADS ○ SUITABLE FOR OPTICAL ALIGN IN FIELD (7.6.2.5)
○ SINGLE SECTION ○ MULTI-SECTION
○ COLUMN MOUNTING (7.6.2.6)
○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ______
○ COMMERCIAL LIFTING ATTA. FURNISHED WITH MAT. AND LOAD TEST CERT. AND ATTESTED BY INDEPENDENT AGENCY (7.6.2.7.7)
○ MACHINED MOUNTING PADS IN SINGLE PLANE AFTER FABRICATION OF BASEPLATE (7.6.2.16)

SOLEPLATES FURNISHED BY: ______
THICKNESS ______ IN
○ SUBPLATES REQUIRED (7.6.2.14)
○ HOLD-DOWN BOLTS FURNISHED BY ______
○ EPOXY PRIMER VENDOR (7.6.1.7.2)
______
○ ANCHOR BOLTS FURNISHED BY (7.6.1.12): ______
○ MOUNTING PLATE FURNISHED BY (7.6.1.1): ______

GEAR UNIT

FURNISHED BY: ______ ○ REFERENCE API 613 ○ OTHER ______
SEE DATASHEETS ______ ______

CONTROL AND INSTRUMENTATION (7.7)

INSTRUMENTS AND CONTROL PANELS SHALL BE IN ACCORDANCE WITH THE FOLLOWING ATTACHED DATASHEETS:
○ API 614, PAGES ______
○ API 670, PAGES ______
○ PURCHASER'S DATASHEETS ______

INSTRUMENTS AND CONTROLS DESIGNED FOR (7.7.1.2) : ○ INDOOR ○ OUTDOOR INSTALLATION
○ INSTRUMENTATION AND CONTROL DESIGN, CONST., INSTALLATION STD. (7.7.1.3) : ______
TERMINAL BOX PROTECTION LEVEL (7.7.1.6) : ○ IP 66 ○ NEMA 4X ○ OTHERS : ______
○ TERMINAL BOX MATERIAL OF CONSTRUCTION (7.7.1.6) : ______
TERMINAL BOX MOUNTING (7.7.3.6) : ○ MOUNTED ON UNIT / BASEPLATE ○ SHIPPED LOOSE : ______
○ PANEL INCLUDES ALL PANEL MOUNTED INSTRUMENTS (7.7.3,1) ○ PURCHASER SPECIFICATION (7.7.3.1) : ______
TERMINAL BOX TAGGING (7.7.3.7) : ○ AS PER VENDOR ○ AS PER PURCHASER STANDARD / SPECIFICATION ______
PANEL LOCATION (7.7.3.1.1) : ○ LOCAL ON BASE OF UNIT ○ OTHERS : ______
○ PANEL MOUNTED INSTRUMENTS (7.7.3.1.2) : ______ ______
○ TOTALLY ENCL. PANEL TO MIN. ELECT. HAZARD, TO PREVENT TAMP. OR TO ALLOW PURG. FOR SAFETY OR CORR. PROTECTION (7.7.3.2.1)

PROTECTIVE DEVICES

	EXHAUST RELIEF VALVE (7.2.2.1) (7.2.2.2) (7.2.1)	EXTRACT./INDUCT. RELIEF VALVE (7.2.2.1)	VACUUM BREAKER (7.7.2.3.12)	NON-RETURN VALVE(S) (7.7.2.3.13 to 7.7.2.3.15)	THERMAL RELIEF VALVE(S) (7.2.1)
MOUNTING LOCATION				X	
SET RELIEF PRESSURE, PISG			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 (7.7.2.5.1)** ○ **TRIP & THROTTLE VALVES (7.7.2.5.1)**

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		

○ **DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (7.7.2.5.2)**

☐ 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 LEAKOFF, lb/h					

TURNING GEAR (7.1)

☐ TURNING GEAR REQUIRED (7.1.1)
○ FURNISHED BY ______
○ TYPE(7.1.5) ______ SPEED ______ r/min
TORQUE : ______ lb-ft
○ ENGAGEMENT (7.1.2) (7.1.3) (7.1.4): ○ AUTO ○ MANUAL
○ MANUFACTURER ______ MODEL ______
○ MOUNTED BY ______
○ DRIVER: REFERENCE SPECIFICATION ______
DRIVEN BY: ○ ELECTRIC MOTOR ○ STEAM TURBINE
(7.1.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______
○ OPERATOR STATION (7.1.7) ○ LOCAL ○ REMOTE

MISCELLANEOUS

○ START-UP ASSISTANCE ______ DAYS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING AND FOUNDATION DRAWINGS (6.1.18) (7.8.2.3)
○ VENDOR WITNESS INITIAL ALIGNMENT ((6.1.18 (a), (b),(c))
☐ "Y" TYPE STRAINER
☐ WATER WASHING CONNECTIONS
○ STATIC CONDUCTING BRUSHES
○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (7.7.2.3.12)
○ BOLT THREAD CONFORM TO (6.1.23.1) : ______
○ STEAM PIPING SCOPE (7.8.2.1) : ______
○ PROGRESS REPORTS (3.3.1 in Annex O): INTERVALS ______
○ ______

INSULATION & JACKETING (7.10)

○ BLANKET ○ OTHER ______
○ JACKETING
○ CARBON STEEL ○ STAINLESS STEEL
○ EXTENT ______

SPECIAL TOOLS (7.9)

○ COUPLING RING AND PLUG GAUGE AND LAPPING PER API 671 (7.3.7)
○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
○ OTHER ______
☐ SPREADER BEAM(S)
○ ON LOAN
○ PURCHASE

ENCLOSURES (7.11)

○ PROVIDED BY VENDOR (7.11.1) : ○ SAFETY ○ FIRE PROTECTION
○ WEATHERPROFFING
○ FAN DRIVEN FORCED VENTILATION AND PURGING SYSTEM (7.11.6)
○ FAN SYSTEM REDUNDANCY (7.11.6) :
○ ADDITIONAL VENTILATION DUCTING (7.11.6.4) ______
○ ACOUSTICAL TREATMENT (7.11.8) : ○ YES ○ NO
○ MAXIMUM ALLOWABLE SPL (7.11.8) : ______ DBA

GROUNDING (7.12)

○ GROUDING BRUSH MOUNTED INSIDE AN ENCLOSURE MEETING WITH WITH ELECTRICAL AREA CLASSIFICATION (7.12.2)

PART LISTS AND RECOMMENDED SPARES (3.4 in Annex O)

○ SPARE PARTS INTERCHANGEABILITY

IOM AND TECHNICAL DATA MANUAL (3.5 in Annex O)

○ DRAFT MANUAL SUBMISSION BEFORE TEST (3.5.1.3 in Annex O)
○ TECHNICAL DATA MANUAL AT SHIPMENT (3.5.4 in Annex O)

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GOVERNOR (7.7.2.1)

TYPE ○ DIGITAL PROCESSOR BASED	○ MANUFACTURER ______ MODEL ______
○ OTHER ______	○ SUPPLIED BY (7.7.5.4): ______
○ SIMPLEX ○ DUPLEX ○ TMR	○ CONTROL MODES (7.7.2.1.21) : ○ SINGLE CONTROL EXT./IND.

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 TYPE

MECHANICAL DRIVE	GENERATOR DRIVE
○ SPEED CONTROL BY:	○ DROOP CONTROL
PROCESS VARIABLE ○ PRESSURE ○ FLOW	○ FREQUENCY CONTROL
EXTRACTION ○ PRESSURE ○ FLOW	○ LOAD CONTROL
INDUCTION ○ PRESSURE ○ FLOW	○ HP CONTROL
TURBINE INLET ○ PRESSURE ○ FLOW	○ HP IMPORT / EXPORT CONTROL
TURBINE EXHAUST ○ PRESSURE ○ FLOW	○ LOAD SHEDDING
OTHER ______	○ AUTOMATIC SYNCHRONIZATION
○ UNUSUAL CONDITIONS ○ REVERSE ROTATION POSSIBLE	○ AUTOMATIC VOLTAGE REGULATION
(6.1.4.2) (6.9.1.4) AFTER TURBINE TRIP	○ TURBINE INLET PRESSURE LIMITING
○ OTHER ______	○ 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 (7.7.2.1.22)
○ OVERSPEED TEST ENABLE	○ INDUCTION CONTROL ENABLED (7.7.2.1.22)
○ 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 ______	○ HP
______	○ HP IMPORT/EXPORT
______	

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GOVERNOR INSTALLATION REQUIREMENTS

LOCATION ◯ LOCAL (AT TURBINE)	MOUNTING ◯ FLUSH MOUNT IN PANEL ◯ SURFACE MOUNT
◯ REMOTE (CONTROL ROOM)	◯ VERTICAL RACK
◯ OTHER ____	POWER SOURCE SINGLE DUAL
◯ AREA CLASSIFICATION:	120 V (a.c.) ◯ ◯
CLASS ___ GROUP ___ DIVISION ___	220 V (a.c.) ◯ ◯
ZONE ___ GROUP ___ TEMP. RATING: ___	125 V (d.c.) ◯ ◯
ENCLOSURE ◯ IP65	24 V (d.c.) ◯ ◯
◯ NEMA 4	____ ◯ ◯
◯ NEMA 4X	____ ◯ ◯
◯ OTHER ____	

LOCAL GOVERNOR CONTROL PANEL ◯ REQUIRED ◯ NOT REQUIRED

LOCATION ◯ LOCAL (AT TURBINE)	ENCLOSURE ◯ IP65
◯ REMOTE CONTROL ROOM	◯ NEMA 4 ◯ NEMA 4X
◯ OTHER ____	◯ OTHER ____ ___
	◯ AREA CLASSIFICATION: ____
OUTPUTS FROM PANEL TO GOVERNOR	CLASS ___ GROUP ___ DIVISION ___
◯ START	ZONE ___ GROUP ___ TEMP. RATING: ___
◯ TRIP	INPUTS TO PANEL FROM GOVERNOR
◯ RAISE	◯ COMMON ALARM TRIP
◯ LOWER	◯ TRIP LAMP
◯ OVERSPEED TEST	◯ REMOTE SET POINT ENABLED LAMP
◯ RAMP TO MINIMUM CONTINUOUS	◯ SPEED SET POINT METER
◯ REMOTE SET POINT ENABLE/DISABLE	◯ SPEED
◯ RESET	◯ OTHER ____
◯ OTHER ____	____

MISCELLANEOUS GOVERNOR DETAILS

GOVERNOR ACTION ON LOSS OF REMOTE SIGNAL: ◯ LOCKS ON LAST VALUE
◯ GOES TO MINIMUM CONTINUOUS
◯ GOES TO MAXIMUM CONTINUOUS

EXTERNAL INTERFACE DEVICE TYPE: ◯ PRINTER FORMAT: ◯ GRAPHIC DISPLAY
◯ CRT ◯ TABULAR DATA
◯ MODEM ◯ TRENDING (REAL TIME)
◯ HISTORICAL ARCHIVING

◯ DISTRIBUTIVE CONTROL SYSTEM MANUFACTURER ____ ◯ MODEL ____
DATA TRANSMISSION ◯ DATA LINK ◯ PROTOCOL ____
◯ DISCRETE I/O
◯ NETWORK TYPE ____

GOVERNOR SPEED PICKUP SENSORS(7.7.2.1.13 to 7.7.2.1.15):
MANUFACTURER ____ MODEL ____ INSTALLATION: ◯ DUAL ◯ TRIPLE ◯ INSTALLED SPARE
◯ NUMBER OF TEETH IN SPEED SENSING SURFACE ____

ACTUATOR(S): ◯ SUPPLIED BY ____ ◯ MANUFACTURER ____ ◯ MODEL ____
ACTUATOR TYPE ◯ HYDRAULIC ◯ PNEUMATIC ◯ SINGLE COIL ◯ MULTI COIL ◯ OTHER ____

TURBINE MOUNTED ACCESSORIES

TACHOMETER ◯ MANUFACTURER ____ ◯ MODEL ____ ◯ NUMBER REQUIRED. ____
◯ LOCATION(S) ____

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TURBINE OVERSPEED SHUTDOWN (TRIP) SYSTEM (7.7.2.3)

○ FURNISHED BY (7.7.5.4) : ______
○ MANUFACTURER ______ ○ MODEL ______
☐ ELECTRONIC, SET POINT ______ r/min
OVERSPEED SHUTDOWN REQUIREMENTS
○ 2 OUT OF 3 VOTING LOGIC (7.7.2.4.4) ○ 2 OUT OF 4 VOTING LOGIC (7.7.2.4.4)
○ ACCELERATION TRIP (7.7.2.2.3)
○ DESIGN CONFIRM TO IEC 6150 / IEC 61511 (7.7.2.3.7)
○ 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 (7.5)

SYSTEM PER: ○ ANNEX F.1 ○ ANNEX F.2 ○ OTHER ______
○ AVAIL. HEADER PRESSURE ______ psig TEMPERATURE ______ °F
○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ psig
○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE ______ °F
☐ SEAL. STM. PRESS. ______ 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 PRESS. ______ psig ☐ STEAM FLOW ______ lb/h
○ VACUUM PUMP (7.5.4), SEE SPECIFICATION ______
○ CONDENSATE RECEIVER
○ LOOP SEAL HEIGHT ______ ft

INSPECTION AND TESTING (8.1) (8.2)(8.3)

GENERAL

○ SHOP INSPECTION (8.1.5)
○ EXT. OF PART. IN INSP. TEST.AND (8.1.1) (8.1.5):
○ AMOUNT OF ADVANCE INSPECTION NOTIFICATION (8.1.1) : ______ WORKING DAYS
COMP. OF INSPECTOR'S CHECKLST (ANNEX M) (8.1.2) : ○ VENDOR ○ PURCHASER ○ BOTH
○ SUBMISSION OF PROPOSED CONNECTION DESIGNS FOR APPROVAL BEFORE FAB.BEGINS (6.11.3.5.1)
○ UNWITNSSED MECHANICAL / PERFORMANCE PRELIMINARY TEST PRIOR TO WITNESSED TEST (8.1.8)

INSPECTION AND MATERIAL TESTING

○ FINAL ASSEMBLY RECORDS REQUIRED (8.2.1.1 f)
○ SUB.OF DETAIL PROC. AND ACCEP. LIMITS FOR THERMAL STABILITY TESTS ON TURBINE ROTOR (8.2.2.8)
○ SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS (6.4.16.2) (6.11.3.4.5) (8.2.1.3) (8.2.2.1.1)

COMPONENT	MAG PART	LIQ PEN	R.T.	U.T.	PMI (6.11.1.11.2) (6.11.1.11.3)	OBSVD	WIT
TRIP & T & T VALVE	○	○	○	○	○	○	○
STEAM CHEST	○	○	○	○	○	○	○
CASING	○	○	○	○	○	○	○
PIPING	○	○	○	○	○	○	○
ROTOR	○	○	○	○	○	○	○
SHAFT SLEEVE	○	○	○	○	○	○	○
BLADES/SHROUDS	○	○	○	○	○	○	○
NOZZLES / BUCKETS	○	○	○	○	○	○	○
LOCKING PINS	○	○	○	○	○	○	○
DIAPHRAGMS	○	○	○	○	○	○	○
PRESSURE PART BOLTS	○	○	○	○	○	○	○

○ HEAT STABILITY (8.2.2.7) ○ ○
○ CLEANLINESS (8.2.3.3) ○ ○
○ HARDNESS (8.2.3.4)) ○ ○
○ CASING HYDROSTATIC TEST (8.3.2) ○ ○
○ BLADE SHAKER TEST (STATIC) (6.6.3.1) ○ ○
○ FACTORY OVERSPEED SHUTDOWN (TRIP) SYSTEM TEST (8.3.4) ○ ○
ROTOR BALANCE ○ STANDARD (6.8.7.1)(6.8.7.2) ○ ○
ROTOR BALANCE ○ OPERATING SPEED (6.8.7.3) ○ ○
○ LOW SPEED PRIOR TO HIGH SPEED (6.8.7.4.8) ○ ○
○ LOW SPEED RESIDUAL UNBALANCE CHECK (6.8.7.7) ○ ○
○ UNBALANCE CHECK AT OPERATING SPEED (6.8.3.2) ○ ○
○ FINAL SURFACE INSPECTION (8.4.5 TO 8.4.12) ○ ○
○ EQUIPMENT INSPECTION (8.4.1) ○ ○
○ ROTOR CRATED (8.4.13.3) ○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT
○ SPARE ROTOR FIT ○ ○
○ CASING JOINT LEAK TEST (8.3.2.2) ○ ○
○ ______ ○ ○

MECHANICAL RUNNING TEST (8.3.3)

	OBSVD	WIT
○ CONTRACT ROTOR	○	○
○ SPARE ROTOR (8.3.3.3.8)	○	○
○ TEST W/JOB COUPLING	○	○
○ TEST TAPE RECORD REQUIRED	○	○
○ TEST TAPE GIVEN TO PURCH.	○	○
○ TEST W/JOB LUBE OIL CONSOLE	○	○
○ SYN. VIB. AMP. AND PHASE ANGLE VS SPEED DECELE. PLOT IN POLAR FORM (8.3.3.3.4)		
○ REAL TIME VIB. DATA (8.3.3.3.6)		
○ ______	○	○
○ ______	○	○
○ ______	○	○

OPTIONAL TESTS AND INSPECTIONS (8.3.6)

	OBSVD	WIT
○ PERFORMANCE TEST (8.3.6.1)	○	○
○ COMPLETE UNIT TEST (8.3.6.2	○	○
○ AUXILIARY EQUIPMENT TEST (8.3.6.3)	○	○
○ CONTROL SYSYEMS	○	○
○ LUBE OIL / DRY GAS SYSTEM	○	○
○ TRIP/TRIP & THROTTLE VALVE TEST (8.3.5)	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ POST-TEST INSPECTION (8.3.6.4)	○	○
○ COUPLING TO SHAFT FIT (API 671) (8.3.6.7)	○	○
○ TURNING GEAR	○	○
○ FIELD OVERSPEED SHUTDOWN (TRIP) SYS. RES. TEST (8.3.6.5)	○	○
○ GOVERNOR RESPONSE (8.3.6.8)	○	○
○ SOUND (8.3.6.9)	○	○
○ SPARE PARTS TESTS (8.3.3.3.9) (8.3.6.6)	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○
○ ______	○	○

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ALARMS AND SHUTDOWNS (7.7.5)

ALARMS (7.7.5.2)

○ 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 (COND. TURBINE) ○ GOVERNOR FAULT
○ TURBINE SHUTDOWN SYSTEM RESPONSE TIME SLOWER THAN THE RESPONSE TIME AS TESTED DURING INSNTALLATION
○ TURBINE SHUTDOWN SYSTEM TRIP OIL HEADER SOLENOID RESPONSE TIME SLOWER THAN THE RESPONSE TIME SPEC. BY SOLENOID VENDOR
○ TURBING GEAR FAIL TO ENGAGE WHEN SHUTDOWN (IF APPLICABLE)
○ ______ ○ ______ ○ ______
○ ______ ○ ______ ○ ______

SHUTDOWNS(7.7.5.2)

○ OVERSPEED DETECTED BY GOVERNOR ○ FAILURE OF ALL GOVERNOR SPEED SENSORS ○ LOW-LOW LUBE OIL PRESSURE
○ HIGH HIGH RADIAL VIBRATION (IF SPEC.) ○ HIGH HIGH AXIAL DISPLACEMENT ○ HIGH HIGH BEARING TEMPERATURE (IF SPEC.)
○ ______ ○ ______ ○ ______
○ ______ ○ ______ ○ ______

AUTOMATED SHUTDOWN (TRIP) (7.7.5.2)

○ OVERSPEED DETECTED BY TURBINE SHUTDOWN SYSTEM (SEE 7.7.2.3)
○ ______ ○ ______

ALARM INTIATOR (7.7.5.5.2) : ○ AUDIBLE WARNING ○ FLASHING LIGHT ○ BOTH ☐ PARAMETER INTIATE ALARM : ______
SHUTDOWN INT. (7.7.5.5.3) : ○ AUDIBLE WARNING ○ FLASHING LIGHT ○ BOTH ☐ PARAMETER INT. SHUTDOWN : ______
○ FIRST OUT ANNUNCIATOR (7.7.5.6) : INDICATE PARAMETER FIRST REACHED ALARAM / SHUTDOWN : ______
○ SEPARATE ANNUCIATOR (7.7.5.6)
○ EVENT RECORDER TO RECORD THE ORDER OF OCCURRENCE OF ALARMS AND SHUTDOWN (7.7.5.7)
○ CAR SEAL OPEN DEVICE FOR SHUTDOWN SENSING DEVICES (7.7.5.9)

MISCELLANEOUS

PAINTING

○ MANUFACTURER'S STANDARD
○ OTHER ______
○ ______

UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI

SHIPMENT [(8.4.1)(8.4.13)]

○ DOMESTIC ○ EXPORT
○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS
○ WATERPROOF BOXING REQUIRED
○ SPARE ROTOR ASSEMBLY PACKAGED FOR (8.4.13.7):
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ SPARE ROTOR ASSEMBLY SHIPPED IN CONTAINER OF NITROGEN PRESSURIZED FOR LONG TERM STORAGE (8.4.14)

WEIGHTS:

☐ TURBINE ______ lb
☐ ROTOR ______ lb
☐ TURBINE UPPER HALF CASING ______ lb
☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ______ lb
☐ TRIP / TRIP & THROTTLE VALVE ______ lb
☐ MISCELLANEOUS ______ lb
☐ TOTAL SHIPPING MASS ______ lb

PACKGE MARKING AND SHIPPING DOCUMENTATION (8.4.27)

ALL MARKING SHALL BE IN (8.4.27.1)
○ ENGLISH ○ OTHER LANG. : ______

CASING APPURTENANCES (6.3)

○ CASING CONNECTIONS WITH VALVESS FOR INERT GAS BLANKET FOR PRESERVATION OF TURBINE AT SITE BEFORE INSTALLATION (6.3.3)
○ OTHER
______
______

☐ **OTHER CONNECTIONS**

	NO.	SIZE	TYPE
LUBE OIL INLET			
LUBE OIL OUTLET			
FIRST STAGE PRESSURE			
STEAM BALANCE PORT			
CASING DRAIN			

SPACE REQUIREMENTS:

	L	W	H
☐ COMPLETE UNIT:	______ in	______ in	______ in
☐ CONTROL PANEL:	______ in	______ in	______ in
☐ OTHER:	______ in	______ in	______ in
☐ OTHER:	______ in	______ in	______ in

VENDOR DRAWING & DATA REQUIREMENTS (9)

○ ANNEX G ○ ANNEX O (9.1.2)
○ DOCUMENTATION TO DEMONSTRATE FIELD PROVEN EQUIPMENT (6.1.3.1)
○ OTHER ______
______

REMARKS AND ADDITIONAL REQUIREMENTS:

A.3 Project Design Datasheets in SI Units

Project Design Data

DOCUMENT NUMBER:

	REVISION	0	1	2	3	4
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	BY					
	REV/APPR					

PROJECT DESIGN DATASHEET SI UNITS (kPa)	JOB NO.	PAGE 1 OF 1
	CLIENT	
	LOCATION	
	UNIT NO.	
	ITEM NO.	
	SERVICE	
APPLICABLE TO: ○ PROPOSAL ◉ PURCHASE ○ AS BUILT	REQ'N NO.	

SITE DESIGN CONDITIONS

AMBIENT DRY BULB TEMPERATURE		RAINFALL / SNOWFALL (mm)	
Average Annual (Summer / Winter)	(°C)	Average, Annual Rainfall	Max 24 Hour Period
Site Maximum (Design)	(°C)	Average, Annual Snowfall	
Site Minimum (Design)	(°C)	SNOW AND ICE LOADING	
Design Basis - Air Cooled Exchangers	(°C)	Ground Snow Load	(mm)
RELATIVE HUMIDITY (%)		RAW WATER SOURCE:	
Average @	(°C)	Temperature: (min/max/design)	(°C)
Maximum @	(°C)	EARTHQUAKE LOADING:	
Minimum @	(°C)	Design Code:	
BAROMETRIC PRESSURE (MAX/MIN)	mmHg	Seismic Zone:	Importance Factor:
SOLAR RADIATION (Heat Flux Intensity)	(W/m²)	Short Period Acceleration (S_S) in %g:	
SITE ELEVATION	(m)	DESIGN WIND SPEED, 3 sec gust:	(km/h)
SITE CONDITIONS:		Wind Design Code:	Site Class:
		Exposure Category:	

UTILITIES

STEAM

Pressure (kPaG)	Rated	Max/Min	Mech Design
High-high			
High			
Medium			
Low			
Temperature (°C)	Rated	Max/Min	Mech Design
High-high			
High			
Medium			
Low			

AIR & NITROGEN

	Pressure (kPaG)			Temperature (°C)	
	Min	Normal	Design	Normal	Design
Instrument					
Plant Air					
Nitrogen (LP)					
Nitrogen (HP)					

Remarks

COOLING WATER

	Press (kPaG)	Temp (°C)
Maximum (Supply/Return)		
Minimum (Supply/Return)		
Max. Differential Temperature		
Allowable Differential Pressure		
System Mech Design		

Source

ELECTRICAL POWER

MOTORS		Voltage	Phase	Hertz
Low Volt: <=	(kW)			
Med Volt: > & ·	(kW)			
High Volt: > & ·	(kW)			
High-High Volt: >	(kW)			
Fractional <=	(kW)			
HEATERS (incl Lube Oil):				
>	(kW)			
<=	(kW)			
Motor Space Htrs >	(kW)			
Motor Space Htrs <	(kW)			
Heaters for panels				
MISCELLANEOUS ELECTRICAL				
Normal Lighting				
U.P.S. - Controls				
U.P.S. - Critical Equip				
Instrument Circuits				
Shutdown / Alarm - Instr.				
Emergency Generator				
Other				

Digital I/O Signals:

Analog I/O Signals:

REMARKS:

A.4 Project Design Datasheets in USC Units

Project Design Data

DOCUMENT NUMBER:

	REVISION	0	1	2	3	4
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	BY					
	REV/APPR					
PROJECT DESIGN DATASHEET U.S. CUSTOMARY	JOB NO.			PAGE 1 OF 1		
	CLIENT					
	LOCATION					
	UNIT NO.					
	ITEM NO.					
	SERVICE					
APPLICABLE TO: ○ PROPOSAL ◉ PURCHASE ○ AS BUILT	REQ'N NO.					

SITE DESIGN CONDITIONS

AMBIENT DRY BULB TEMPERATURE		RAINFALL / SNOWFALL (in)	
Average Annual (Summer / Winter)	(°F)	Average, Annual Rainfall	Max 24 Hour Period
Site Maximum (Design)	(°F)	Average, Annual Snowfall	
Site Minimum (Design)	(°F)	SNOW AND ICE LOADING	
Design Basis - Air Cooled Exchangers	(°F)	Ground Snow Load	(in)
RELATIVE HUMIDITY (%)		RAW WATER SOURCE:	
Average @	(°F)	Temperature: (min/max/design)	(°F)
Maximum @	(°F)	EARTHQUAKE LOADING:	
Minimum @	(°F)	Design Code:	
BAROMETRIC PRESSURE (MAX/MIN)	mmHg	Seismic Zone:	Importance Factor:
SOLAR RADIATION (Heat Flux Intensity)	(BTU/ft²)	Short Period Acceleration (S_S) in %g:	
SITE ELEVATION	(ft)	DESIGN WIND SPEED, 3 sec gust:	(mph)
SITE CONDITIONS:		Wind Design Code:	Site Class:
		Exposure Category:	

UTILITIES

STEAM

Pressure (psig)	Rated	Max/Min	Mech Design
High-high			
High			
Medium			
Low			
Temperature (°F)	Rated	Max/Min	Mech Design
High-high			
High			
Medium			
Low			

AIR & NITROGEN

	Pressure (psig)			**Temperature** (°F)	
	Min	Normal	Design	Normal	Design
Instrument					
Plant Air					
Nitrogen (LP)					
Nitrogen (HP)					

Remarks

COOLING WATER

	Press (psig)	Temp (°F)
Maximum (Supply/Return)		
Minimum (Supply/Return)		
Max. Differential Temperature		
Allowable Differential Pressure		
System Mech Design		

Source

ELECTRICAL POWER

MOTORS		Voltage	Phase	Hertz
Low Volt: <=	(HP)			
Med Volt: > & ·	(HP)			
High Volt: > & ·	(HP)			
High-High Volt: >	(HP)			
Fractional <=	(HP)			
HEATERS (incl Lube Oil):				
>	(kW)			
<=	(kW)			
Motor Space Htrs >	(kW)			
Motor Space Htrs <	(kW)			
Heaters for panels				
MISCELLANEOUS ELECTRICAL				
Normal Lighting				
U.P.S. - Controls				
U.P.S. - Critical Equip				
Instrument Circuits				
Shutdown / Alarm - Instr.				
Emergency Generator				
Other				

Digital I/O Signals:

Analog I/O Signals:

REMARKS:

Annex B
(informative)

Steam Turbine Nomenclature

B.1 Introduction

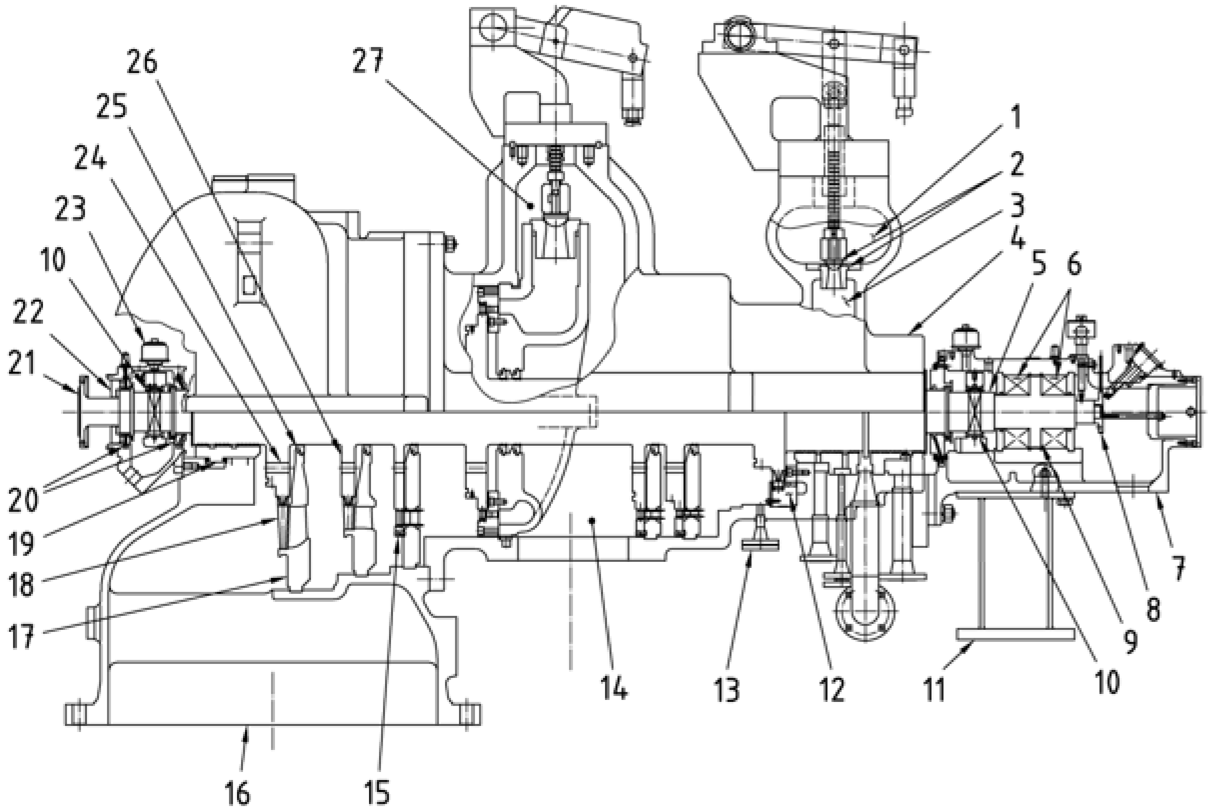
Figure B.1 and Figure B.2 are included only to clarify the nomenclature for standard machine parts and are in no way intended to show preferred design solutions or establish any design requirements whatsoever. The machine parts depicted here might not all be present in each turbine or might have a different 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.

NOTE 1 In a controlled extraction steam turbine, control of shaft output power and process steam pressure is achieved by automatically regulating the extraction steam flow. In a controlled induction steam turbine, control of shaft output power and process steam pressure is achieved by automatically regulating the induction steam flow.

NOTE 2 In an uncontrolled extraction steam turbine, the pressure of the extracted steam decreases with increase in the extraction flow from the turbine. The steam flow is determined by the pressure drop and piping resistance from the steam pressure at the extraction opening to the pressure at the (external) destination. Control valves are typically not used to regulate steam flow on an uncontrolled extraction turbine. Check valves (nonreturn valves) can be installed in the extraction line, upstream of a relief valve (if provided), to prevent unintended backflow of steam from the process piping into the turbine and to minimize momentary rotor overshoot speed following an overspeed trip event.

NOTE 3 In a controlled induction (or admission) steam turbine, one or more regulating valves are interposed in the normal steam flow of the turbine steam path and situated to present a restriction to steam flowing to the turbine exhaust. As the regulating valves are moved to the opened position, steam enters the turbine through an opening in the casing that is upstream of these valves. The turbine speed and shaft power, as well as the induction steam mass flow rate, and pressure of the extracted steam can be controlled by modulating either the induction control valves and/or inlet steam flow.

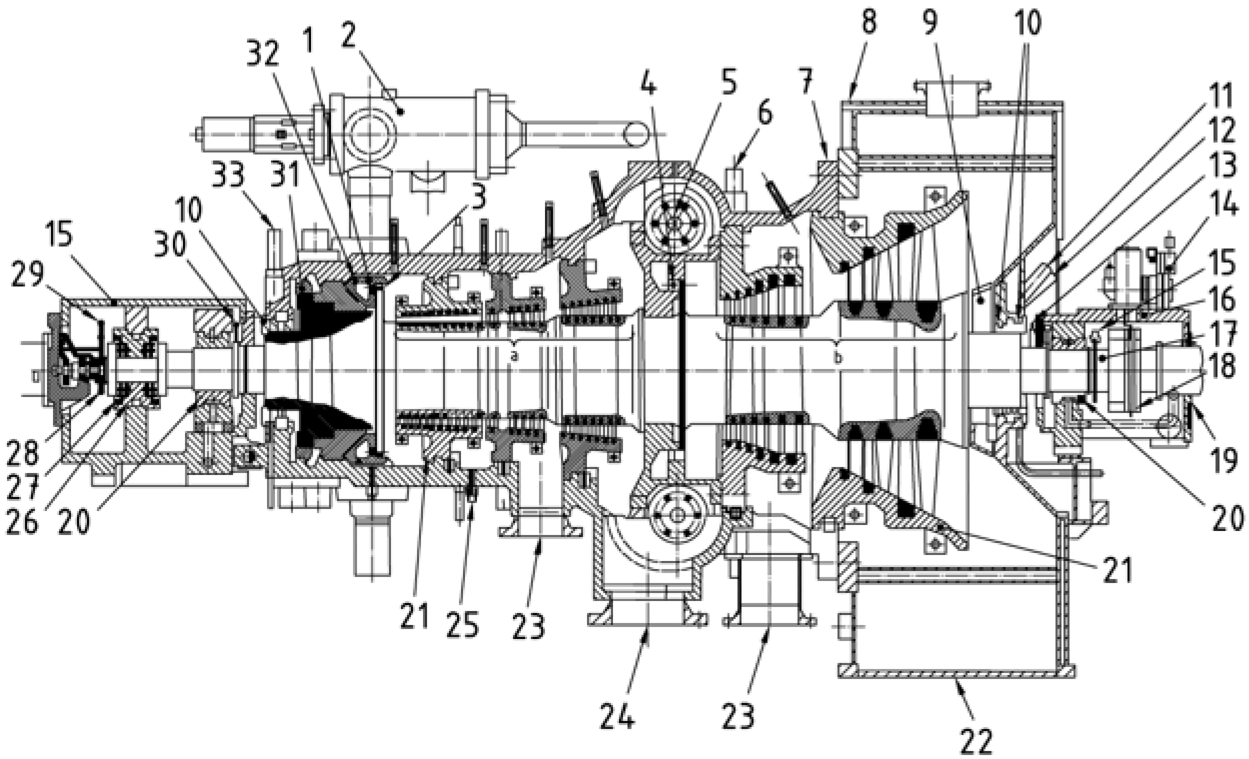
NOTE 4 In an uncontrolled induction (or admission) steam turbine, steam from an external source is introduced into a turbine casing, typically into an intermediate point of the turbine steam path. The supply pressure from the external source is greater than the steam pressure at the intermediate point of the turbine steam path. Steam flow from an uncontrolled induction turbine is determined by the pressure drop and piping resistance from the external source to the steam turbine destination.



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)

Steam Purity and Variations in Steam Conditions

C.1 Steam Purity

C.1.1 Steam turbine users shall be aware of the hazards associated with contamination of the steam by agents that may promote stress corrosion cracking, solids buildup, erosion, and corrosion. Contaminants such as sodium, hydroxides, chlorides, sulfates, copper, lead, and silicates may result in shortened turbine life and failure of internal parts of the turbine.

C.1.2 Since it is not possible to prescribe the degree of contamination that steam turbine materials may tolerate to achieve the long life expected of internal turbine components, only general guidelines are included in Table C.1.

Table C.1—Steam Purity Limits

Contaminant	Continuous	Start-up
Conductivity— Micromhos/cm at 25 °C (77 °F)	—	—
Drum	0.3	1.0
Once through	0.2	0.5
SiO (ppb), max	20	50
Fe (ppb), max	20	50
Cu (ppb), max	3	10
Na + K (ppb), max	—	—
Up to 5516 kPag (800 psig)	20	20
5517 kPag to 9998 kPag (801 psig to 1450 psig)	10	10
9999 kPag to 16,548 kPag (1451 psig to 2400 psig)	5	5
Over 16,548 kPag (2400 psig)	3	3

C.2 Variations in Steam Conditions

C.2.1 The rating, capability, steam flow, speed regulation, and pressure control shall be based on operation at maximum steam conditions.

NOTE Maximum steam conditions are the highest inlet steam pressure and temperature and exhaust pressure to which the turbine is subjected in continuous operation.

C.2.2 Steam turbines shall be capable of operating under the following variations in inlet pressure and temperature, but performance shall not necessarily be in accordance with the standards established for operating at maximum steam conditions. Continuous operation at other than maximum steam conditions shall require review by the turbine vendor.

C.2.2.1 Variations from Maximum Inlet Steam Pressure

C.2.2.1.1 The turbine shall be capable of operating without damage at less than the guaranteed steam flow to the turbine with average inlet pressure of 105 % of maximum inlet steam pressure (this permissible variation recognizes the increase in pressure with decrease in steam flow encountered in operation).

C.2.2.1.2 The inlet steam pressure shall average not more than maximum pressure over any 12-month operating period. The inlet steam pressure shall not exceed 110 % of maximum pressure in maintaining these averages, except during abnormal conditions.

C.2.2.1.3 During abnormal conditions, the steam pressure at the turbine inlet connection shall be permitted to exceed maximum pressure briefly by as much as 20 %, but the aggregate duration of such swings beyond 105 % of maximum pressure shall not exceed 12 hours per 12-month operating period.

C.2.2.2 Variations from Maximum Inlet Steam Temperature

C.2.2.2.1 The inlet steam temperature shall average not more than maximum temperature over any 12-month operating period.

C.2.2.2.2 In maintaining this average, the temperature shall not exceed maximum temperature by more than 8 °C (46 °F) except during abnormal conditions. During abnormal conditions, the temperature shall not exceed maximum temperature by more than 14 °C (57 °F) for operating periods of not more than 400 hours per 12-month operating period nor by more than 28 °C (82 °F) for swings of 15 minutes duration or less, aggregating not more than 80 hours per 12-month operating period.

C.2.2.3 Variations from Maximum Exhaust Steam Pressure on Noncondensing Turbines

C.2.2.3.1 The exhaust steam pressure shall average not more than the maximum exhaust steam pressure over any 12-month operating period.

C.2.2.3.2 In maintaining this average, the exhaust steam pressure shall not exceed maximum pressure by more than 10 % nor drop more than 20 % below the maximum exhaust pressure.

C.2.2.4 Variations in Exhaust Steam Pressure on Condensing Turbines

Any anticipated variations in the exhaust steam pressure specified by the purchaser on the datasheet shall be considered in the design of the turbine.

Annex D
(normative)

Allowable Forces and Moments

D.1 Allowable Forces and Moments on Steam Turbines

D.1.1 The forces and moments acting on steam turbines due to the steam inlet, extraction, and exhaust connections shall be limited by the following.

D.1.1.1 The total resultant force and total resultant moment imposed on the turbine at any connection shall not exceed the value calculated by Equation (D.1).

In SI units:

$$0.674FR + 0.738MR \leq 19.7 D_e \tag{D.1a}$$

In USC units:

$$3FR + MR \leq 500 D_e \tag{D.1b}$$

where

FR	resultant force in N (lbf) at the connection; it is calculated by Equation (D.3); this includes pressure forces where unrestrained expansion joints are used except on vertical down exhausts; full vacuum load is allowed on vertical down exhaust flanges; it is not included as part of the piping load from Figure D.1;
MR	resultant moment in N·m (lbf-ft) at the connection from Figure D.1; it is calculated by Equation (D.4);
D_e	NPS of the connection in millimeters up to 200 mm DN (NPS 8) in diameter; for sizes greater than this, use value calculated by Equation (D.2).

In SI units:

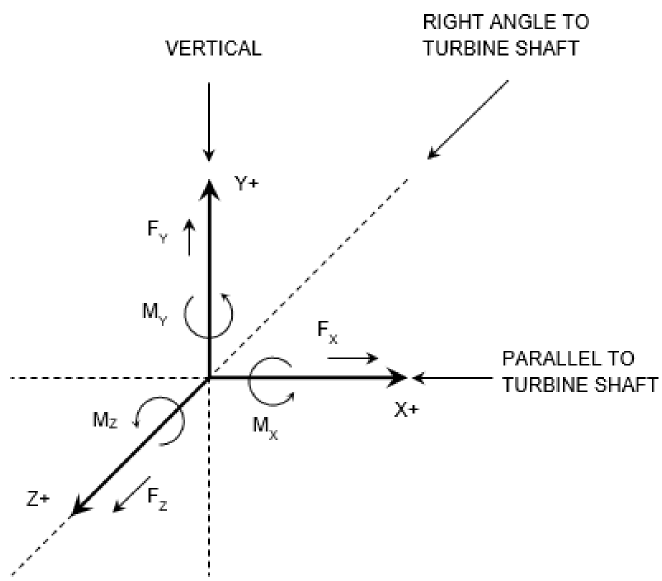
$$D_e = \frac{(406 + Nominal\,Diameter)}{3} \tag{D.2a}$$

In USC units:

$$D_e = \frac{(16 + Nominal\,Diameter)}{3} \tag{D.2b}$$

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2} \tag{D.3}$$

$$M_R = \sqrt{M_x^2 + M_y^2 + M_z^2} \tag{D.4}$$



NOTE Positive moments rotate counterclockwise when viewed looking into positive forces.

Figure D.1—Components of Forces and Moments on Turbine Construction

D.1.1.2 The combined resultants of the forces and moments of the inlet, extraction, and exhaust connections, resolved at the centerlines of the exhaust connection, shall not exceed the values calculated by Equation (D.5).

In SI units:

$$0.450F_c + 0.738M_c \le 9.84D_c \quad \text{(D.5a)}$$

In USC units:

$$2F_c + M_c \le 250D_c \quad \text{(D.5b)}$$

where

F_c	is the combined resultant of inlet, extraction, and exhaust forces, N (lbf);
M_c	is the combined resultant of inlet, extraction, and exhaust moments, and moments resulting from forces, N·m (lbf-ft);
D_c	is the diameter in mm (in.) of a circular opening equal to the total areas of the inlet, extraction, and exhaust openings up to a value of 229 mm (9 in.) in diameter; for diameter greater than this, use a value of D_c calculated by Equation (D.6).

In SI units:

$$D_c = \frac{(457 + Nominal\,Diameter)}{3} \quad \text{(D.6a)}$$

In USC units:

$$D_c = \frac{(18 + Nominal\,Diameter)}{3} \quad \text{(D.6b)}$$

The components (see Figure D.1) of these resultants shall not exceed the values given in Equation (D.7).

In SI units:

$$
\begin{aligned}
F_x &= 8.76 D_c \\
F_y &= 21.9 D_c \\
F_z &= 17.5 D_c \\
M_x &= 13.3 D_c \\
M_y &= 6.67 D_c \\
M_z &= 6.67 D_c
\end{aligned} \tag{D.7a}
$$

In USC units:

$$
\begin{aligned}
F_x &= 50 D_c \\
F_y &= 125 D_c \\
F_z &= 100 D_c \\
M_x &= 250 D_c \\
M_y &= 125 D_c \\
M_z &= 125 D_c
\end{aligned} \tag{D.7b}
$$

where

F_x	is the horizontal components of F_c parallel to the turbine shaft, mm (in.);
F_y	is the vertical component of F_c, mm (in.);
F_z	is the horizontal component of F_c at right angles to the turbine shaft, mm (in.);
M_x	is the component of M_c around the horizontal axis parallel to the turbine shaft, N·m (lbf-ft);
M_y	is the component of M_c around the vertical axis, N·m (lbf-ft);
M_z	is the component of M_c around the horizontal axis at right angles to the turbine shaft, N·m (lbf-ft).

Allowable forces and moments for turbines with various inlet and exhaust sizes are shown in Table D.1 and Table D.2.

D.1.1.3 For condensing turbines with a vertical down exhaust and an unrestrained expansion joint at the exhaust, an additional amount of force (i.e. the vertical force component on the exhaust connection excluding pressure loading) shall be calculated.

D.1.1.3.1 This calculated vertical force component shall be used in the equations in D.1.1.1 and D.1.1.2 to determine the total resultant force on the exhaust connection.

NOTE This additional force is perpendicular to the face of the exhaust flange and central.

D.1.1.3.2 The force caused by the pressure loading on the exhaust is allowed in addition to the values established in D.1.1.3.1 up to a maximum value of vertical force in newtons on the exhaust connection (including pressure loading) of 0.107 times the area in square millimeters [in pounds on the exhaust connection (including pressure loading) of 15.5 times the exhaust area in square inches].

D.1.1.4 The values of allowable forces and moments in Table D.1 and Table D.2 pertain to the turbine structure only. They do not pertain to the forces and moments in the connecting piping, flange, and flange bolting, which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

Table D.1—Allowable Forces and Moments (SI Units)

Inlet (mm)	Exhaust (mm)	F_x (N)	F_y (N)	F_z (N)	M_x (N·m)	M_y (N·m)	M_z (N·m)
50	150	1385	3463	2767	2103	1055	1055
50	200	1806	4515	3608	2742	1375	1375
80	150	1489	3723	2975	2261	1134	1134
80	200	1887	4717	3770	2865	1437	1437
100	200	1959	4897	3913	2974	1491	1491
100	250	2121	5303	4238	3221	1615	1615
100	300	2258	5646	4512	3429	1720	1720
100	400	2539	6347	5072	3855	1933	1933
100	450	2681	6703	5356	4071	2041	2041
100	500	2824	7060	5641	4287	2150	2150
100	600	3111	7778	6215	4724	2369	2369
100	750	3544	8861	7081	5381	2699	2699
100	900	3979	9948	7949	6041	3030	3030
150	300	2314	5786	4624	3514	1762	1762
150	400	2582	6456	5159	3921	1966	1966
150	450	2720	6800	5434	4130	2071	2071
150	500	2859	7148	5712	4341	2177	2177
150	600	3141	7852	6275	4769	2392	2392
150	750	3568	8921	7129	5418	2717	2717
150	900	3999	9998	7989	6072	3045	3045
200	300	2388	5970	4770	3625	1818	1818
200	400	2641	6602	5276	4010	2011	2011
200	450	2773	6932	5540	4210	2111	2111
200	500	2907	7269	5808	4414	2214	2214
200	600	3182	7954	6356	4831	2423	2423
200	750	3602	9004	7195	5468	2742	2742
200	900	4027	10,068	8045	6114	3066	3066
200	1200	4887	12,218	9764	7420	3721	3721
250	300	2475	6188	4945	3758	1885	1885
250	400	2712	6781	5419	4118	2065	2065
250	450	2838	7095	5670	4309	2161	2161
250	500	2967	7418	5928	4505	2259	2259
250	600	3233	8083	6459	4909	2462	2462
250	750	3643	9109	7279	5532	2774	2774
250	900	4063	10,156	8116	6168	3093	3093
250	1200	4914	12,286	9817	7461	3742	3742
300	450	2914	7286	5822	4425	2219	2219
300	500	3038	7594	6068	4612	2313	2313
300	600	3294	8235	6580	5001	2508	2508
300	750	3694	9234	7379	5608	2812	2812
300	900	4105	10,263	8201	6233	3126	3126
300	1200	4947	12,367	9882	7511	3767	3767

Table D.1—Allowable Forces and Moments (SI Units) (Continued)

Inlet (mm)	Exhaust (mm)	F_x (N)	F_y (N)	F_z (N)	M_x (N·m)	M_y (N·m)	M_z (N·m)
400	600	3441	8602	6873	5224	2620	2620
400	750	3817	9543	7625	5795	2906	2906
400	900	4211	10,527	8412	6393	3206	3206
400	1200	5029	12,571	10,046	7635	3829	3829
NOTE Sizes of inlet and exhaust nozzles are DN.							

Table D.2—Allowable Forces and Moments (USC Units)

Inlet (in.)	Exhaust (in.)	F_x (lb)	F_y (lb)	F_z (lb)	M_x (lb-ft)	M_y (lb-ft)	M_z (lb-ft)
2	6	316	791	632	1581	791	791
2	8	412	1031	825	2062	1031	1031
3	6	335	839	671	1677	839	839
3	8	427	1068	854	2136	1068	1068
4	8	447	1118	894	2236	1118	1118
4	10	480	1199	959	2398	1199	1199
4	12	511	1277	1022	2554	1277	1277
4	16	575	1437	1150	2874	1437	1437
4	18	607	1518	1215	3037	1518	1518
4	20	640	1600	1280	3200	1600	1600
4	24	706	1764	1411	3528	1764	1764
4	30	804	2011	1609	4022	2011	2011
4	36	904	2259	1807	4518	2259	2259
6	12	524	1309	1047	2618	1309	1309
6	16	585	1462	1170	2924	1462	1462
6	18	616	1541	1232	3081	1541	1541
6	20	648	1620	1296	3240	1620	1620
6	24	712	1781	1425	3562	1781	1781
6	30	810	2025	1620	4050	2025	2025
6	36	908	2271	1817	4541	2271	2271
8	12	540	1351	1081	2702	1351	1351
8	16	598	1495	1196	2991	1495	1495
8	18	628	1571	1257	3141	1571	1571
8	20	659	1648	1318	3295	1648	1648
8	24	722	1804	1443	3608	1804	1804
8	30	817	2044	1635	4087	2044	2044
8	36	915	2287	1829	4573	2287	2287
8	48	1111	2778	2222	5555	2778	2778
10	12	560	1401	1121	2802	1401	1401
10	16	614	1536	1229	3072	1536	1536
10	18	643	1608	1286	3216	1608	1608
10	20	673	1682	1345	3363	1682	1682
10	24	733	1833	1467	3667	1833	1833
10	30	827	2068	1654	4135	2068	2068

Table D.2—Allowable Forces and Moments (USC Units) (Continued)

Inlet (in.)	Exhaust (in.)	F_x (lb)	F_y (lb)	F_z (lb)	M_x (lb-ft)	M_y (lb-ft)	M_z (lb-ft)
10	36	923	2307	1845	4614	2307	2307
10	48	1117	2793	2234	5586	2793	2793
12	18	661	1651	1321	3303	1651	1651
12	20	689	1722	1377	3444	1722	1722
12	24	747	1868	1494	3736	1868	1868
12	30	839	2096	1677	4193	2096	2096
12	36	932	2331	1865	4662	2331	2331
12	48	1125	2812	2249	5623	2812	2812
16	24	781	1952	1561	3904	1952	1952
16	30	867	2167	1733	4333	2167	2167
16	36	957	2391	1913	4783	2391	2391
16	48	1143	2858	2287	5716	2858	2858
NOTE Sizes of inlet and exhaust nozzles are NPS.							

D.1.1.5 See sample problems 1, 2, and 3 for examples of how force and moment limitations are applied to turbine installations.

NOTE Sample problems 1.a, 2.a, and 3.a are in SI units. Sample problems 1.b, 2.b, and 3.b are in USC units.

D.2 Sample Problem 1.a (SI Units) (Allowable Forces and Moments on Steam Turbines)

A steam turbine has a 100 mm side inlet and a 200 mm side exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the force and moments imposed on the inlet and exhaust flange as listed below.

Inlet flange:

$F_x = +178N$ $M_x = +271$ N·m

$F_y = –445N$ $M_y = +203$ N·m

$F_z = –331N$ $M_x = –163$ N·m

Exhaust flange:

$F_x = –489N$ $M_x = +678$ N·m

$F_y = –1112N$ $M_y = +407$ N·m

$F_z = +801N$ $M_x = +475$ N·m

D.2.1 Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (D.1a).

Inlet flange:

$$F_R = \sqrt{((178)^2 + (-455)^2 + (-311)^2)} = 571N$$

$$M_R = \sqrt{(271)^2 + (203)^2 + (-163)^2} = 376N \cdot m$$

D_e = 100 mm (correction is not needed for flanges 200 mm and smaller)

$$0.674FR(N) + 0.738MR(N \cdot m) \leq 19.7D_e(mm)$$

$$(0.674)(571) + (0.738)(376) \leq (19.7)(100)$$

662 ≤ 1970 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (D.1a).

Exhaust flange:

$$F_R = \sqrt{(-490)^2 + (1113)^2 + (801)^2} = 1456N$$

$$M_R = \sqrt{(680)^2 + (408)^2 + (476)^2} = 925N \cdot m$$

D_e = 200 mm (correction is not needed for flanges 200 mm and smaller)

$$0.674F_R + 0.738M_R \leq 19.7D_e$$

$$(0.674)(1456) + (0.738)925 \leq (19.7)(200)$$

1664 ≤ 3940 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (D.1a).

D.2.2 Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (D.5a).

F_x = 178 + (–489) = –311N

F_y = –445N + (–1112) = –1557N

F_z = –331 + 801 = +490N

M_x = 271 + 678 = +949 N·m

M_y = 203 + 407 = +610 N·m

M_z = –163 + 475 = +312 N·m

$$F_c = \sqrt{(-311)^2 + (-1557)^2 + (490)^2} = 1662 \text{ N}$$

$$M_c = \sqrt{(949)^2 + (610)^2 + (312)^2} = 1170 \text{ N} \cdot \text{m}$$

Nominal inlet flange area = $\frac{\pi(100\,mm)^2}{4} = 7854\,mm^2$

Nominal exhaust flange area = $\frac{\pi(200\,mm)^2}{4} = 31,416\,mm^2$

Total flange area = 7854 + 31,416 = 39,270 mm^2

$D_e = \sqrt{\frac{(4)(39,270)}{\pi}}$ = 224 mm (correction is not needed for flanges 229 mm and smaller)

$$0.450F_c + 0.735M_c \leq 9.84D_c$$

$$(0.449)(1662) + (0.735)(1170) \leq (9.84)(224)$$

1608 ≤ 2204 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (D.5a).

D.2.3 Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (D.7a).

Allowable forces and moments:

F_x = 8.76 (D_c) = 1962 N; |–311 N| < 1962 N

F_y = 21.9 (D_c) = 4906 N; |–1557 N| < 4906 N

F_z = 17.5 (D_c) = 9811 N; |+490 N| < 3920 N

M_x = 13.3 (D_c) = 2979 N·m; |+949 N·m| < 2979 N·m

M_y = 6.67 (D_c) = 1494 N·m; |+610 N·m| < 1494 N·m

M_z = 6.67 ($\mathrm{D_c}$) = 1494 N·m; |+312 N·m| < 1494 N·m

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (D.7a).

Results from Parts 1, 2, and 3 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (D.7a).

D.3 Sample Problem 2.a (SI Units) (Allowable Forces and Moments on Steam Turbines)

A condensing turbine has a 150 mm side inlet and a 900 mm down exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the forces and moments imposed on the inlet and exhaust flanges (excluding force on the exhaust flange due to pressure forces in the unrestrained expansion joint in the exhaust line) as listed below.

Inlet flange:

F_x = +400 N M_x = –475 N·m

F_y = –667 N M_y = +271 N·m

F_z = +890 N M_z = +203 N·m

Exhaust flange:

F_x = 0 N M_x = 0 N·m

F_y = –1112 N M_y = 0 N·m

F_z = 0 N M_z = 0 N·m

Bellows area for the expansion joint (obtained from expansion joint manufacturer) is 664,515 mm². Pressure force developed by full vacuum in the expansion joint is:

$$(0.101 \ {}^{N}\!/\!{}_{mm^2})(640{,}000 \ mm^2) = 64{,}640 \ N$$

This is additional force in the –Y direction.

D3.1 Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (D.1a).

Inlet flange:

$$F_R = \sqrt{(400)^2 + (-667)^2 + (890)^2} = 1182 \ N$$

$$M_R = \sqrt{(-475)^2 + (271)^2 + (203)^2} = 583 \ N \cdot m$$

D_e = 150 mm (correction is not needed for flanges 200 mm and smaller)

$$0.674 F_R + 0.738 M_R \leq 19.7 D_e$$

$$(0.674)(1182) + (0.738)(583) \leq (19.7)(150)$$

1227 ≤ 2955 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (D.1a).

Exhaust flange:

FR excluding pressure force =

$$F_R = \sqrt{(0)^2 + (-1112)^2 + (0)^2} = 1112 \ N$$

$$M_R = \sqrt{(0)^2 + (0)^2 + (0)^2} = 0 \ N \cdot m$$

$D_{exhaust}$ 900 mm > 203 mm, therefore:

$$D_e = \frac{(406 + 900)}{3} = 435 \ mm$$

$$0.674 F_R + 0.738 M_R \leq 19.7 D_e$$

$$(0.674)(1112) + (0.738)(0) \leq (19.7)(435)$$

749 ≤ 8570 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (D.1a).

D.3.2 Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (D.5a).

F_x = 400+ 0 = +400 N

F_y = –667 + (–1112) = –1779 N

F_z = 890 + 0 = +890 N

M_x = –475 + 0 = -475 N·m

M_y = 271 + 0 = +271 N·m

M_z = 203 + 0 = +203 N·m

$$F_c = \sqrt{(400)^2 + (-1779)^2 + (890)^2} = 2029 N$$

$$M_c = \sqrt{(-475)^2 + (271)^2 + (203)^2} = 583 N \times m$$

Nominal inlet flange area $\frac{\pi(150\,mm)^2}{4} = 17,671\,mm^2$

Nominal exhaust flange area $= \frac{\pi(900\,mm)^2}{4} = 636,173\,mm^2$

Total flange area = 17,671 + 636,173 = 653, 844 mm²

$D_c = \sqrt{\frac{(4)(53,844)}{\pi}}$ = 912 mm(value is greater than 229 mm, therefore correction is required)

$$D_c = \frac{(457 + 912)}{3} = 456 \text{ mm}$$

$$0.450 F_c + 0.735 M_c \leq 9.84 D_c$$

$$(0.450)(2029) + (0.735)(583) \leq (9.84)(456)$$

1342 ≤ 4487 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (D.5a).

D.3.3 Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (D.7a). Allowable forces and moments:

F_x = 8.76(D_c) = 3995 N; |+400 N| < 3995 N

F_y = 21.9(D_c) = 9986 N; |–1779 N| < 9986 N

F_z = 17.5(D_c) = 7980 N; |+890 N| < 7980 N

M_x = 13.39(D_c) = 6106 N·m; |–475 N·m| < 6106 N·m

M_y = 6.67(D_c) = 3042 N·m; |+271 N·m| < 3042 N·m

M_z = 6.67(D_c) = 3042 N·m; |+203 N·m| < 3042 N·m

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (D.7a).

D.3.4 Part 4

Check total force on the turbine exhaust flange against the limit in D.1.1.3.2. This paragraph states that force on the exhaust flange should not exceed 0.107 times the nominal exhaust area.

(0.107) (636,173 mm^2) = 68,070 N

Total force on the exhaust flange is the vector total of pressure force from the expansion joint and the forces calculated with pressure force excluded.

Total force = −64,640 + (−1112) = −65,752 N

|−65,752 N| < 68,070 N

Results from Parts 1, 2, 3, and 4 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (D.7a) and D.1.1.3.2.

D.4 Sample Problem 3.a (SI Units)

Table D.3 shows allowable forces and moments for a steam turbine with four extraction openings.

Table D.3—Extraction Openings for a Steam Turbine

Opening	Size of Opening (mm)	Area of Opening (mm^2)
Inlet	350	96,211
Extraction #1	250	49,087
Extraction #2	200	31,416
Extraction #3	400	125,664
Extraction #4	750	441,786
Exhaust	3800	11,341,149

Find the diameter of a circular opening equal to the total area:

$$\text{Equivalent diameter} = \sqrt{\frac{4(96,211 + 49,087 + 31,416 + 125,664 + 441,786 + 11,341,149)}{\pi}}$$

Equivalent diameter = 3923 mm

Correct the equivalent diameter if the value exceeds 229 mm.

$$D_c = \frac{457 + 3923}{3} = 1460 \text{ mm}$$

Calculate the maximum allowable forces and moments:

F_x = 8.76(1460) = 12,790 N

F_y = 21.9(1460) = 31,974 N

F_z = 17.5(1460) = 25,550 N

M_x = 13.3 (1460) = 19,418 N·m

M_y = 6.67(1460) = 9738 N·m

M_z = 6.67(1460) = 9738 N·m

D.5 Sample Problem 1.b (USC Units)

(Allowable Forces and Moments on Steam Turbines)

A steam turbine has a 4 in. side inlet and an 8 in. side exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the force and moments imposed on the inlet and exhaust flange as listed below.

Inlet flange:

F_x = +40 lb M_x = +200 lb-ft

F_y = –100 lb M_y = +150 lb-ft

F_z = –70 lb M_z = –120 lb-ft

Exhaust flange:

F_x = –110 lb M_x = +500 lb-ft

F_y = –250 lb M_y = +300 lb-ft

F_z = +180 lb M_z = +350 lb-ft

D.5.1 Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (D.1b).

Inlet flange:

$$F_R = \sqrt{(40)^2 + (-100)^2 + (-70)^2} = 128 \text{ lb}$$

$$M_R = \sqrt{(200)^2 + (150)^2 + (-120)^2} = 277 \text{ lb-ft}$$

D_e = 4 in. (correction is not needed for flanges 8 in. and smaller)

$$3F_R + M_R \leq 500D_e$$

$$(3)(128) + 277 \leq (500)(4)$$

661 ≤ 2000 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (D.1b).

Exhaust flange:

$$F_R = \sqrt{(-110)^2 + (-250)^2 + (180)^2} = 327 \text{ lb}$$

$$M_R = \sqrt{(500)^2 + (300)^2 + (350)^2} = 680 \text{ lb-ft}$$

D_e = 8 in. (correction is not needed for flanges 8 in. and smaller)

$$3F_R + M_R \leq 500D_e$$

$$(3)(327) + 680 \leq (500)(8)$$

1661 ≤ 4000 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (D.1b).

D.5.2 Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (D.5b).

F_x = 40 + (–110) = –70 lb

F_y = –100 + (–250) = –350 lb

F_z = –70 + 180 = +110 lb

M_x = 200 + 500 = +700 lb-ft

M_y = 150 + 300 = +450 lb-ft

M_z = –120 + 350 = +230 lb-ft

$$F_c = \sqrt{(-70)^2 + (-350)^2 + (110)^2} = 373 \text{ lb}$$

$$M_c = \sqrt{(700)^2 + (450)^2 + (230)^2} = 863 \text{ lb-ft}$$

Nominal inlet flange area = $\frac{\pi(4\,in.)}{4} = 12.57 in.^2$

Nominal exhaust flange area = $\frac{\pi(8\,in.)}{4} = 50.27 in.^2$

Total flange area = 12.57 + 50.27 = 62.84 in.^{2}

$$2F_c + M_c \leq 250D_c$$

$$(3)(373) + 863 \leq (250)(8.94)$$

1609 ≤ 2235 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (D.5b).

D.5.3 Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (D.7b).

Allowable forces and moments:

$F_x = 50(D_c)$ = 447 lb; |–70 lb| < 447 lb

$F_y = 125(D_c)$ = 1118 lb; |–350 lb| < 1,118 lb

$F_z = 100(D_c)$ = 894 lb; |+110 lb| < 894 lb

$M_x = 250(D_c)$ = 2236 lb-ft; |+700 lb-ft| < 2236 lb

$M_y = 125(D_c) = 1118$ lb-ft; $|+450 \text{ lb-ft}| < 1118$ lb

$M_z = 125(D_c) = 1118$ lb-ft; $|+230 \text{ lb-ft}| < 1118$ lb

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (D.7b).

Results from parts 1, 2, and 3 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (D.7b).

D.6 Sample Problem 2.b (USC Units)

D.6.1 Allowable Forces and Moments on Steam Turbines

A condensing turbine has a 6 in. side inlet and a 36 in. down exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the forces and moments imposed on the inlet and exhaust flanges (excluding force on the exhaust flange due to pressure forces in the unrestrained expansion joint in the exhaust line) as listed below.

Inlet flange:

$F_x = +90$ lb $M_x = -350$ lb-ft

$F_y = -150$ lb $M_y = +200$ lb-ft

$F_z = +200$ lb $M_z = +150$ lb-ft

Exhaust flange:

$F_x = 0$ lb $M_x = 0$ lb-ft

$F_y = -250$ lb $M_y = 0$ lb-ft

$F_z = 0$ lb $M_z = 0$ lb-ft

Bellows area for the expansion joint (obtained from expansion joint manufacturer) is 1030 in.^{2}. Pressure force developed by full vacuum in the expansion joint is:

$$(14.7\ {}^{lb}\!/_{in.})(1030\,in.^2) = 15,141\,lb$$

This is additional force in the –Y direction.

D.6.2 Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (D.1b).

Inlet flange:

$$F_R = \sqrt{(90)^2 + (-150)^2 + (200)^2} = 266 \text{ lb}$$

$$M_R = \sqrt{(-350)^2 + (200)^2 + (150)^2} = 430 \text{ lb-ft}$$

D_e = 6 in. (correction is not needed for flanges 8 in. and smaller)

$$3F_R + M_R \leq 500\ D_e$$

$$(3)(266) + 430 \leq (500)(6)$$

1228 ≤ 3000 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (D.1b).

Exhaust flange:

FR excluding pressure force =

$$F_R = \sqrt{(0)^2 + (250)^2 + (0)^2} = 250 \text{ lb}$$

$$M_R = \sqrt{(0)^2 + (0)^2 + (0)^2} = 0 \text{ lb-ft}$$

$D_{exhaust}$ 36 in. > 8 in., therefore:

$$D_e = \frac{(16 + 36)}{3} = 17.33 \text{ in.}$$

$$3F_R + M_R \leq 500 D_e$$

$$(3)(250) + 0 \leq (500)(17.33)$$

750 ≤ 8665 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (D.1b).

D.6.3 Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (D.5b).

Fx = 90 + 0 = +90 lb

Fy = –150 – 250 = –400 lb

Fz = 200 + 0 = +200 lb

Mx = –350 + 0 = –350 lb-ft

My = 200 + 0 = +200 lb-ft

Mz = 150 + 0 = +150 lb-ft

$$F_c = \sqrt{(90)^2 + (-400)^2 + (200)^2} = 456 \text{ lb}$$

$$M_c = \sqrt{(-350)^2 + (200)^2 + (150)^2} = 430 \text{ lb-ft}$$

Nominal inlet flange area = $\frac{\pi(6 \text{ in.})^2}{4} = 28.3 \text{ in.}^2$

Nominal exhaust flange area = $\frac{\pi(36 \text{ in.})^2}{4} = 1017.9 \text{ in.}^2$

Total flange area = 28.3 + 1071.9 = 1046.2 in.^{2}

$$D_c = \sqrt{\frac{(4)(1046.2)}{\pi}} = 36.5 \text{ in. (value is greater than 9 in., therefore correction is required)}$$

$$D_c = \frac{(18 + 36.5)}{3} = 18.166 \text{ in.}$$

$$2F_c + M_c \leq 250\ D_c$$

$$(2)(456) + 430 \leq (250)(18.166)$$

1342 ≤ 4542 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (D.5b).

D.6.4 Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (D.7b).

Allowable forces and moments:

$F_x = 50(D_c)$ = 908 lb; |+90 lb| < 447 lb

$F_y = 125(D_c)$ = 2271 lb; |–400 lb| < 1118 lb

$F_z = 100(D_c)$ = 1817 lb; |+90 lb| < 894 lb

$M_x = 250(D_c)$ = 4541 lb-ft; |–350 lb-ft| < 2236 lb

$M_y = 125(D_c)$ = 2271 lb-ft; |+200 lb-ft| < 1118 lb

$M_z = 125(D_c)$ = 2271 lb-ft; |+150 lb-ft| < 1118 lb

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (D.7b).

D.2.4 Part 4

Check total force on the turbine exhaust flange against the limit per paragraph D.1.1.3.2. This paragraph states that force on the exhaust flange should not exceed 15-$^1/_2$ times the nominal exhaust area.

(15 $^1/_2$) (1017.9 in.^{2}) = 15,777 lb

Total force on the exhaust flange is the vector total of pressure force from the expansion joint and the forces calculated with pressure force excluded.

Total force = −15,141 – 250 = −15,391 lb

Results from Parts 1, 2, 3, and 4 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (D.7b) and D.1.1.3.2.

D.7 Sample Problem 3.b (USC Units)

D.7.1 Allowable Forces and Moments for a Steam Turbine with Four Extraction Openings

D.7.1.1 Table D.4 shows size openings for steam turbines.

Table D.4—Extraction Openings for a Steam Turbine

Opening	Size of Opening (in.)	Area of Opening (in.^{2})
Inlet	14	153.94
Extraction #1	10	78.54
Extraction #2	8	50.26
Extraction #3	16	201.06
Extraction #4	30	706.86
Exhaust	148	17,203.40

Find the diameter of a circular opening equal to the total area:

$$\text{Equivalent diameter} = \sqrt{\frac{4(153.94 + 78.54 + 50.26 + 201.06 + 706.86 + 17{,}203.40)}{\pi}}$$

Equivalent diameter = 153.02 in.

Correct the equivalent diameter if the value exceeds 9 in.

$$D_c = \frac{18 \quad + \quad 153.04}{3} = 57.01\,in.$$

Calculate the maximum allowable forces and moments:

F_x = 50(57.01) = 2851 lb

F_y = 125(57.01) = 7126 lb

F_z = 100(57.01) = 5701 lb

M_x = 250(57.01) = 14,253 lb-ft

M_y = 125(57.01) = 7126 lb-ft

M_z = 125(57.01) = 7126 lb-ft

Annex E
(normative)

Calculation of the Maximum Rotor Speed During an Overspeed Trip

E.1 Scope

E.1.1 Following the initiation of a trip by the overspeed trip system, the speed of the rotor system increases 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, if a valve has linear response characteristic, $f = 0.5$.

c) The energy input to the turbine from steam (or condensate that may flash to steam) contained within the turbine system when the turbine is operating at maximum output. This steam expands to the exhaust pressure. The energy from this source may be partly or wholly expanded during the time the stop valves (such as trip valve and non-return valve) are closing or after the valves have closed if the steam is trapped in a region downstream of the stop valves such as in extraction piping. It is assumed that a certain fraction of this energy 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 may be calculated using the peak kinetic energy and inertia of the rotor. See Figure E.1.

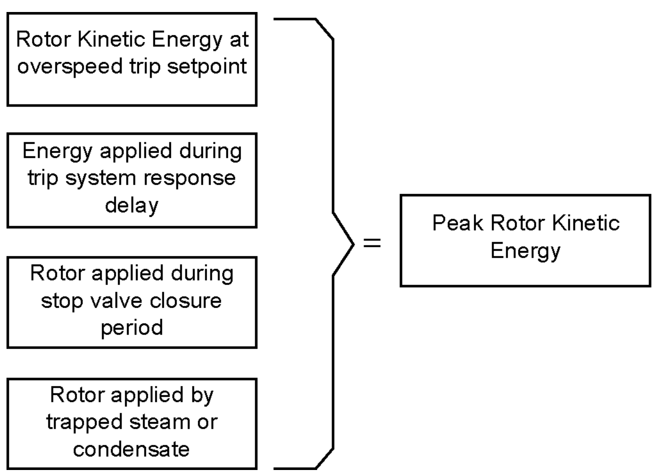


Figure E.1—Peak Kinetic Energy of the Rotor

E.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 tend to be conservative (actual excursion shall be less than the calculated excursion) because the energy consumed by the parasitic losses (bearing friction, windage) and the energy absorbed by the driven equipment (if connected) has not been subtracted from the total energy of the rotor after the trip sequence is initiated.

NOTE The accuracy of these calculations can be improved if these losses are included.

E.2 Calculations in SI Units

a) The instantaneous rotor acceleration αt at the overspeed trip setting is determined by:

$$\alpha_t = k \times \frac{P_{g(\max)}}{N_T \times WR^2{}_T} \text{ (rpm/s) (turbine rotor uncoupled)} \quad \text{(E.1)}$$

$$\alpha_t = k \times \frac{P_{g(\max)}}{N_T \times WR^2{}_C} \text{ (rpm/s) (complete train)} \quad \text{(E.2)}$$

where

k	equals 9.119 × 104, (kg-m^2·rpm2) / (kW-s);
$P_{g(\max)}$	is the turbine rated power, kW;
NT	is the set point of overspeed trip device, rpm;
$WR^2{}_T$	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*, is calculated by:

$$E = k_2 \times WR^2 \times N^2 \, (kW - s) \quad \text{(E.3)}$$

$$E_T = k_2 \times WR^2{}_T \times N_T{}^2 \, (kW - s)\text{(turbine rotor uncoupled)} \quad \text{(E.4)}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 (kW - s)\text{(complete train)} \quad \text{(E.5)}$$

where

E_T	is the rotor kinetic energy at overspeed trip set point, kW-s;
k_2	equals 5.483 × 10−6, (kW-s) / (kg-m^2·rpm^2).

The energy added to the rotor during the signal delay time is calculated by:

$$\Delta E_S = T_S \times P_{g(\max)}(kW - s) \quad \text{(E.6)}$$

where

T_s	is the signal time delay (seconds)—the period of time between when an overspeed shutdown condition occurred and the time the shutdown valve(s) starts to close. This time period includes sensor delays, logic solver I/O scan rate delays, logic solver program scan rate delays × 2 (this is the worst-case delay), shutdown solenoid delays, and shutdown oil-header delays.

c) The energy added to the rotor during the closure time of the stop valve is calculated by:

$$\Delta E_V = f \times T_v \times P_{g(\max)}(kW - s) \quad \text{(E.7)}$$

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.

NOTE Stop valves typically have characteristics that result in f being less than 1 but greater than 0.5. The stop valve manufacturer can furnish typical values off for the valve in question.

d) The energy added to the rotor by the expansion of steam that is trapped within the turbine is calculated by:

$$\Delta E_e = k_3 \eta \left[\sum W_{1i} u_{1i} - \sum W_{2i} u_{2i} - \sum (W_{1i} - W_{2i}) h_{2i} \right] (kW - s) \quad \text{(E.8)}$$

where

k_3	1.000 kW-s/kJ;
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, kg;
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, kJ;
W_{2i}	is the weight of steam in the "i" spaces defined for after W_{1i} expansion has ceased, kg;
u_{2i}	is the internal energies for the W_{2i} masses of steam in the "i" spaces after isentropic expansion, kJ;
h_{2i}	is the enthalpies of the W_{2i} masses of steam after isentropic expansion, kJ/kg.

e) The maximum kinetic energy of the rotor is 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.

$$E_{\max} = E_T + E_S + E_v + E_e (kW - s) \quad \text{(E.9)}$$

f) The maximum speed attained by the rotor is calculated by rearranging Equations (E.4) and (E.5) as follows.

$$N_{\max} = \sqrt{\frac{E_{\max}}{k_2 \times WR^2{}_T}} \text{ (rpm) (turbine rotor uncoupled)} \quad \text{(E.10)}$$

$$N_{max} = \sqrt{\frac{E_{max}}{k_2 \times WR^2{}_C}} \text{ (rpm) (complete train)} \quad \text{(E.11)}$$

E.3 Calculations for Generator Drive and Mechanical Drive

E.3.1 Generator Drive

a) The instantaneous rotor acceleration αt at the overspeed trip setting is determined by:

$$\alpha_t = k \times \frac{P_{g(\max)}}{N_T \times WR^2{}_T} \text{ (rpm) (turbine rotor uncoupled)} \quad \text{(E.12)}$$

$$\alpha_t = k \times \frac{P_{g(\max)}}{N_T \times WR^2{}_C} \text{ (rpm) (complete train)} \quad \text{(E.13)}$$

where

k	equals 2.164 × 106, (rpm²·lbm-ft²) / (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-ft²;
$WR^2{}_T$	is the rotational inertia of turbine rotor (uncoupled), lb-ft²;
$WR^2{}_C$	$WR^2$is the rotational inertia of the complete train, lb-ft².

b) The kinetic energy of the rotor at a given speed, N, is calculated by:

$$E = k_2 \times WR^2 \times N^2 (kW - s) \tag{E.14}$$

$$E_T = k_2 \times WR^2{}_T \times N_T{}^2 (kW - s)\text{(turbine rotor uncoupled)} \tag{E.15}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 (kW - s)\text{(complete train)} \tag{E.16}$$

where

E_T	is the rotor kinetic energy at overspeed trip set point, HP-s;
k_2	equals 2.311 × 10−7, (kW-s) / (rpm²·lbm-ft²).

c) The energy added to the rotor during the signal delay time is:

$$\Delta E_s = T_s \times P_{g(max)} (kW - s) \tag{E.17}$$

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:

$$\Delta E_v = f \times T_v \times P_{g(max)} (kW - s) \tag{E.18}$$

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.

NOTE Stop valves typically have characteristics that result in *f* being less than 1 but greater than 0.5. The stop valve manufacturer can 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:

$$\Delta E_e = k_3 \eta \left[\sum W_{1i} u_{1i} - \sum W_{2i} u_{2i} - \sum (W_{1i} - W_{2i}) h_{2i} \right] (kW - s) \tag{E.19}$$

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;

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;

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 is 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, with zero generator electrical load.

$$E_{max} = E_T + E_s + E_v + E_e (kW - s) \quad \text{(E.20)}$$

g) The maximum speed attained by the rotor is calculated by rearranging Equations (E.15) and (E.16), as follows.

$$N_{max} = \sqrt{\frac{E_{max}}{k_2 \times WR^2{}_T}} \text{ (rpm) (turbine rotor uncoupled)} \quad \text{(E.21)}$$

$$N_{max} = \sqrt{\frac{E_{max}}{k_2 \times WR^2{}_C}} \text{ (rpm) (complete train)} \quad \text{(E.22)}$$

E.3.2 Mechanical Drive

a) The instantaneous rotor acceleration αt at the overspeed trip setting is determined by:

$$a_t = k \times \frac{P_{g(max)}}{N_T \times WR^2{}_T} \text{ (rpm/s) (turbine rotor uncoupled)} \quad \text{(E.23)}$$

$$a_c = k \times \frac{P_{g(max)}}{N_T \times WR^2{}_C} \text{ (rpm/s) (complete train)} \quad \text{(E.24)}$$

where

k equals 1.614 × 106, (rpm^2.lbm-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 is the rotational inertia of a rotor, lb-ft^2;

$WR^2{}_T$ 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, is calculated by:

$$E = k_2 \times WR^2 \times N^2 (HP - s) \quad \text{(E.25)}$$

$$E_T = k_2 \times WR^2{}_T \times N_T{}^2 (HP - s) \text{ turbine rotor uncoupled} \quad \text{(E.26)}$$

$$E_T = k_2 \times WR^2{}_C \times N_T{}^2 (HP - s) \text{complete train} \quad \text{(E.27)}$$

where

E_T is the rotor kinetic energy at overspeed trip set point, HP-s;

k_2 equals 3.099 × 10−7, (HP-s)/(rpm²·lbm-ft²);

c) The energy added to the rotor during the signal delay time is:

$$\Delta E_s = T_s \times P_{g(max)} (HP - s) \tag{E.28}$$

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:

$$\Delta E_v = f \times T_v \times P_{g(max)} (HP - s) \tag{E.29}$$

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.

NOTE Stop valves typically have characteristics that result in *f* being less than 1 but greater than 0.5. The stop valve manufacturer can 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:

$$\Delta E_e = k_3 \eta \left[\sum W_{1i} u_{1i} - \sum W_{2i} u_{2i} - \sum (W_{1i} - W_{2i}) h_{2i} \right] (HP - s) \tag{E.30}$$

where

k_2 1.415 HP-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;

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;

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 is 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.

$$E_{max} = E_T + E_S + E_v + E_e - E_d (HP - s) \tag{E.31}$$

where

E_d is the energy absorbed by the driven equipment.

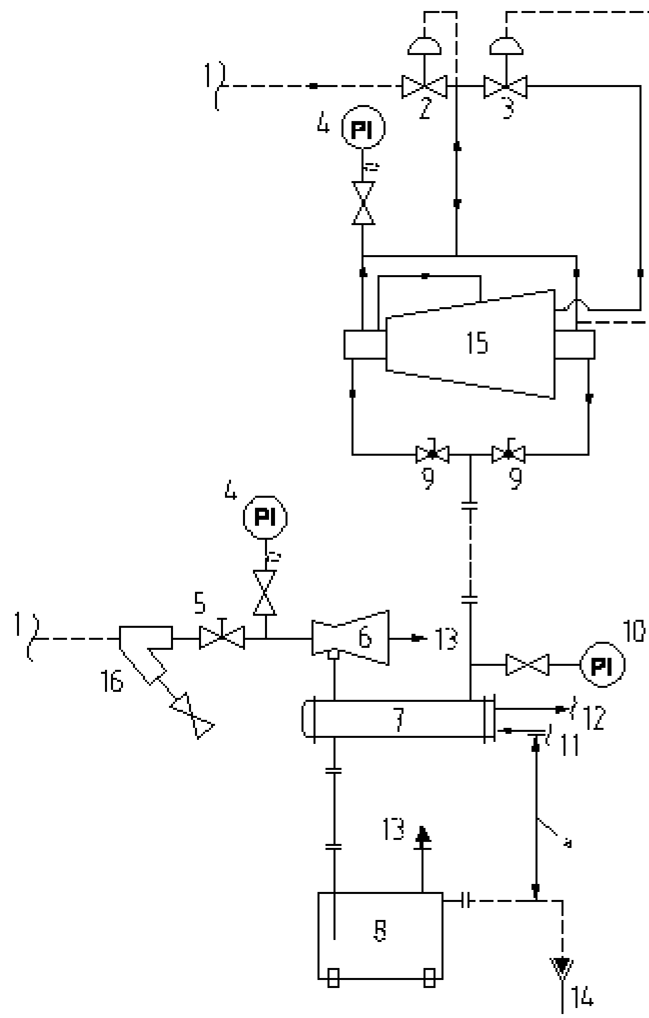
g) The maximum speed attained by the rotor is calculated by rearranging Equations (E.26) and (E.27), as follows.

$$N_{max} = \sqrt{\frac{E_{max}}{k_2 \times WR^2{}_T}} \text{ (rpm) (turbine rotor uncoupled)} \quad \text{(E.32)}$$

$$N_{max} = \sqrt{\frac{E_{max}}{k_2 \times WR^2{}_C}} \text{ (rpm) (complete train)} \quad \text{(E.33)}$$

Annex F
(informative)

Gland Sealing and Leak-off System



Key

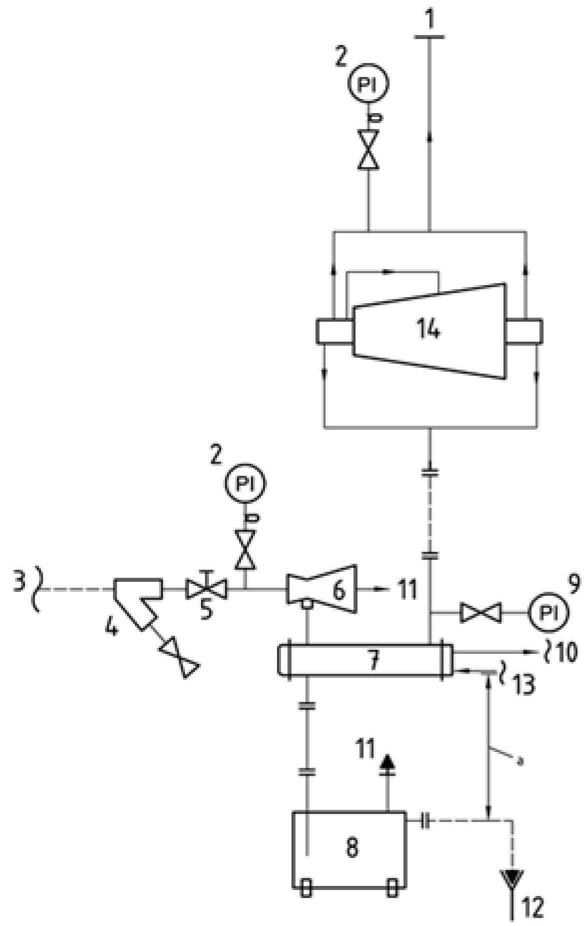
1 dry steam supply
2 pressure reducing valve
3 back-pressure regulator
4 pressure gauge
5 flow-control valve
6 air ejector (vacuum pump if specified)
7 gland condenser
8 condensate seal tank
9 flow adjusting valve (only if specified)
10 vacuum gauge
11 cooling water supply
12 cooling water return
13 vent
14 drain
15 turbine
16 steam strainer

——— 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
(normative)

Vendor Drawing and Data Requirements (VDDR)

G.1 Example VDDR Form

Special-purpose Steam Turbine Vendor Drawing and Data Requirement

For ______________________________
Site ______________________________
Service ______________________________

Job No. ____________ Item No. ____________
Purchase Order No. ________ Date: ____________
Requisition No. ________ Date: ____________
Enquiry No. ________ Date: ____________
Page ________ of ________ By ____________
Revision ______________________________
Unit ______________________________
No. Required ______________________________

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

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

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

Distribution record

Final – Received from vendor
Final – Due from vendor
Review – Returned from vendor
Review – Received from vendor
Review – Due from vendor

Proposal	Review	Final		Description	Review – Due from vendor	Review – Received from vendor	Review – Returned from vendor	Final – Due from vendor	Final – Received from vendor
			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-rate 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)	Mechanical running test procedure					
			ff)	Procedures for other specified shop tests					
			gg)	Hydro test logs (certified)					
			hh)	Mechanical running test logs (certified)					
			ii)	Nondestructive test procedures					

[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 to 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____________

For________________________________ Revision________________________________
Site________________________________ Unit ________________________________
Service_____________________________ No. Required ____________________________

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

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

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

Distribution record

Final – Received from vendor
Final – Due from vendor
Review – Returned from vendor
Review – Received from vendor
Review – Due from vendor

			Description					
			jj) Mill test reports (certified)					
			kk) Rotor balance logs					
			ll) Rotor combined mechanical and electrical runout report					
			mm) As-built datasheets					
			nn) As-built dimensions and data					
			oo) Installation manual					
			pp) Operating and maintenance manuals					
			qq) Spare parts list					
			rr) Progress reports and delivery schedule					
			ss) Drawing list					
			tt) Shipping list					
			uu) List of special tools					
			vv) Technical data manual					
			ww) Preservation, packing, and shipping procedures					
			xx) Recommended equipment rigging and lifting instructions					
			yy) Vibration-probe sensing area/shaft drawing					
			zz) Material safety datasheets					

[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 to 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)

G.2 Description

A description of the components (see example VDDR form list in G.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, and

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 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) through v) with off-design steam, as follows:

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

2) inlet temperature to maximum and minimum values listed on the datasheets in increments agreed 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 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 driving synchronous generators.

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) Mechanical running test procedure, including available shop steam inlet, and exhaust conditions.

ff) Procedures for other specified shop tests.

gg) Certified hydro test logs.

hh) 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 (see 8.3.3.2.4).

ii) Nondestructive test procedures and acceptance criteria as itemized on the purchase order datasheets or the VDDR form.

jj) Certified mill test reports of items as agreed in the precommitment or preinspection meetings.

kk) Rotor balance logs, including a residual unbalance report in accordance with Annex J.

ll) Rotor combined mechanical and electrical.

mm) As-built datasheets.

nn) 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 of:

i) shaft,

ii) wheels or bladed disks,

iii) thrust collar, and

iv) blades, vanes, and nozzles.

oo) Installation manual describing the following (see O.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.

pp) Operating and maintenance manuals describing the following (see O.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 should 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) through 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 gg),

   iv) mechanical running test logs, as specified in Item hh),

   v) rotor balancing logs, as specified in Item kk),

   vi) rotor mechanical and electrical runout at each journal, as specified in Item ll),

   vii) physical and chemical mill certificates, as specified in Item jj), 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, and

xiii) trip/combined trip and throttle-valve construction drawings.

qq) Spare parts list with stocking level recommendations, in accordance with O.3.4.

rr) Progress reports and delivery schedule, including vendor buyouts and milestones, in accordance with O.3.3.

ss) Drawing list, including latest revision numbers and dates.

tt) Shipping list, including all major components that will ship separately.

uu) List of special tools furnished for maintenance.

vv) 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) through w);

3) drawings, in accordance with O.3.2;

4) as-built assembly clearances;

5) spare parts list, in accordance with O.3.4;

6) utility data;

7) vibration data, as specified in item x);

8) reports, as specified in Items y) through aa), cc), ii), and ss);

9) datasheets (e.g. Annex A).

ww) Preservation, packaging, and shipping procedures.

xx) Recommended equipment rigging and lifting instructions (see 8.4.11).

yy) Vibration-probe sensing area/shaft drawing that accurately locates sensing areas on the shaft axis that are not to be metallized, sleeved, or plated.

zz) Material safety datasheets (e.g. OSHA Form 174).

Annex H
(normative)

Report Requirements for Lateral and Stability Analyses

H.1 Standard Lateral Analysis and Stability Report

a) Rotor model:

1) sketch of rotor model;

2) clear identification of bearing, shaft end and internal labyrinth seals, probe, coupling, and turbine wheel locations.

b) Oil film bearings:

1) dynamic coefficients (plot or table) for minimum and maximum stiffness cases vs speed and power;

2) in the stability analysis, the synchronous and/or nonsynchronous coefficients if used by manufacturer;

3) identification of coordinate system including direction of rotation;

4) bearing type, length, pad arc length, diameter, minimum and maximum clearance and corresponding preload range, offset, number of pads and pivot type, materials (ball and socket if applicable), and geometry;

5) bearing load and direction vs speed and power;

6) oil properties and operating conditions:

i) oil viscosity (two-temperature data if a nonstandard ISO Grade),

ii) oil flow rate and/or inlet pressure,

iii) inlet operating temperature range,

iv) oil specific gravity,

v) seal operating conditions.

c) Bearing pedestal data:

1) identify parameters vs frequency (mass, stiffness, and damping).

d) Other forces included in the analysis (machine dependent):

1) generator stator magnetic stiffness.

NOTE Vendor typically provides force magnitude and basis of calculation.

e) Analysis methods:

1) list computer codes used in the analysis with a brief description of the type of code, e.g. finite element, CFD, transfer matrix.

f) Undamped critical speed map and mode shapes:

1) critical speed vs support stiffness;

2) curves of the support stiffness (i.e. K_{xx} and K_{yy} for minimum and maximum stiffness), where K_{xx} is horizontal stiffness and K_{yy} is vertical stiffness;

3) plot, as a minimum, the first four critical speeds with the stiffness axis extending from “free-free” to “rigid” support” regions;

4) show the minimum allowable speed and N_{mc};

5) the map shall be displayed as shown in Figure H.1;

6) undamped mode shapes from the free-free, expected, and rigid support regions;

7) for machines that do not have similar support stiffness, the critical speed map shall indicate the specified reference bearing and its location; for each of the other bearing locations, the bearing stiffness ratio, relative to the specified reference bearing, shall be defined.

NOTE The vendor can substitute mode shape plots for the undamped critical speed map and list the undamped critical speeds and the support stiffness for each of the identified modes.

g) Unbalance response predictions:

1) identification of the frequency of each critical speed in the range from 0 to 150 % of N_{mc} ;

2) frequency, phase, and amplitude (Bode plots) at the vibration probe locations in the range 0 to 150 % of N_{mc} resulting from the unbalances specified in 6.8.2.8:

i) if location of the vibration probes is outside the requirements of API 670, then the Bode plots shall be shown at the bearing centerline and probe;

ii) minimum allowable and N_{mc} shown;

3) tabulation of critical speeds, AF and actual and required separation margin;

4) axial location, amount, and phase of unbalance weights for each case;

5) plots of amplitude and phase angle vs speed at probe locations:

i) for min and max bearing stiffness cases,

ii) pedestal vibration amplitudes for flexible pedestals as defined in 6.8.2.3 e);

6) scale factor (S_{CC}) or multiple of API residual unbalance;

7) plots of deflected rotor shape at critical speeds and N_{mc} for minimum and maximum bearing stiffness cases;

8) a table of the close clearance magnitudes and locations and maximum vibration levels verifying that 6.8.2.11 has been met.

h) Stability analysis:

1) description of all assumptions used in the analysis;

2) description of all dynamic effects included in the analysis;

3) the calculated anticipated cross coupling, q_a, total anticipated cross coupling, Q_A, log dec and damped natural frequency at anticipated cross coupling, and Q_0/Q_A;

4) Figure H.2 plot of log dec vs cross coupled stiffness for min and max bearing stiffness;

5) value of log dec and frequency versus component addition for min and max bearing stiffness;

6) summary sheet that identifies compliance with API requirements.

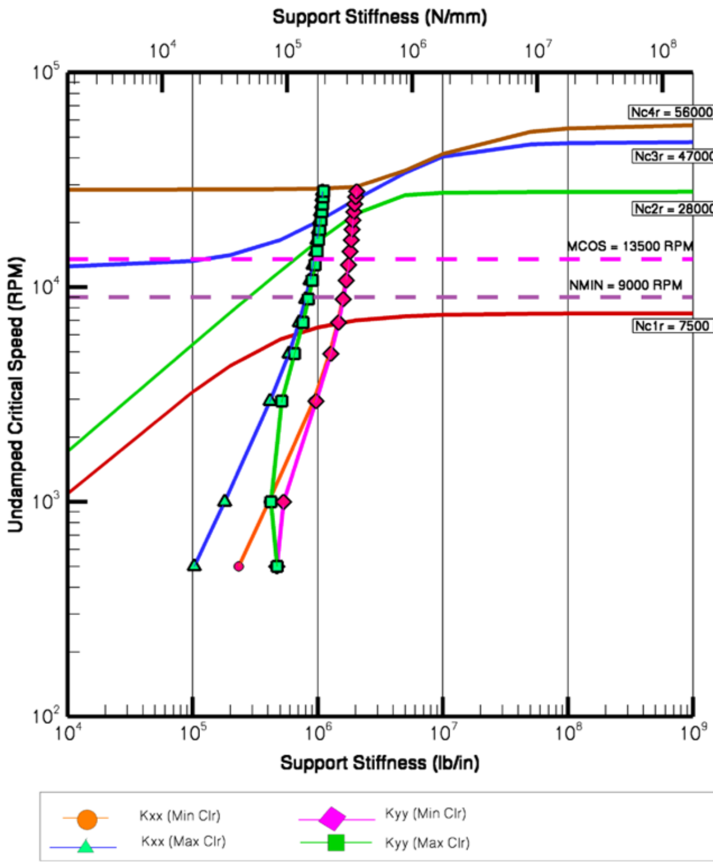


Figure H.1—Undamped Critical Speed Map

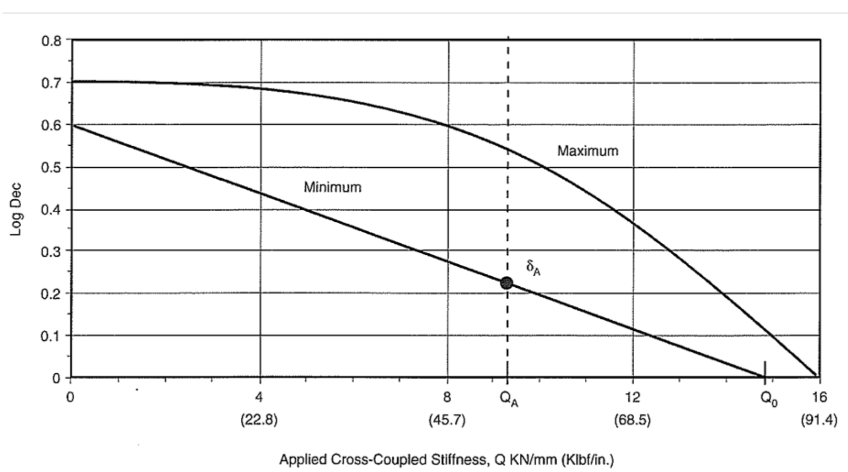


Figure H.2—Stability Sensitivity Plot

H.2 Data Required to Perform Independent Audits of Lateral and Stability Analysis

a) All requirements of H.1 shall be met. This requirement details additional data that shall be provided in conjunction with the Standard Lateral Analysis and Stability Report or as an addendum to it.

b) Rotor model:

1) model tabulation to include rotor geometry (including delineation between stiffness and mass diameter);

2) the weight, polar and transverse moments of inertia, attachment location and center of gravity of the wheels and coupling;

3) shaft material properties (density and Young's modulus).

c) Bearings:

1) data to permit independent calculation of bearing coefficients:

i) Table H.1, Figure H.3, and Figure H.4 indicate geometry required for tilt pad bearings.

d) Internal labyrinth seals:

1) dimensional data;

2) clearance assumptions.

Table H.1—Tilt Pad Bearing Dimensions and Tolerances

Dimension	Nominal	Tolerance (+)	Tolerance (−)
Shaft diameter at journal $(2 \times R_j)$			
Pad machined diameter $(2 \times R_p)$			
Set bore $(2 \times R_b)$			
Pivot offset (α)		n/a	
Pad arc length (χ)		n/a	

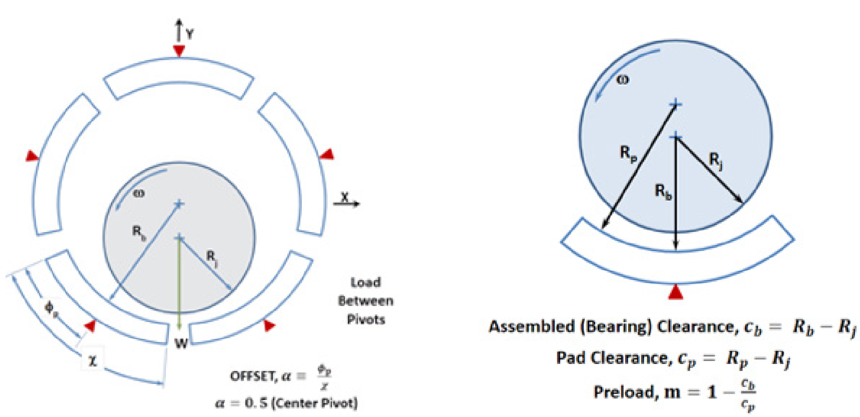


Figure H.3—Geometry Definitions for Tilt Pad Bearing

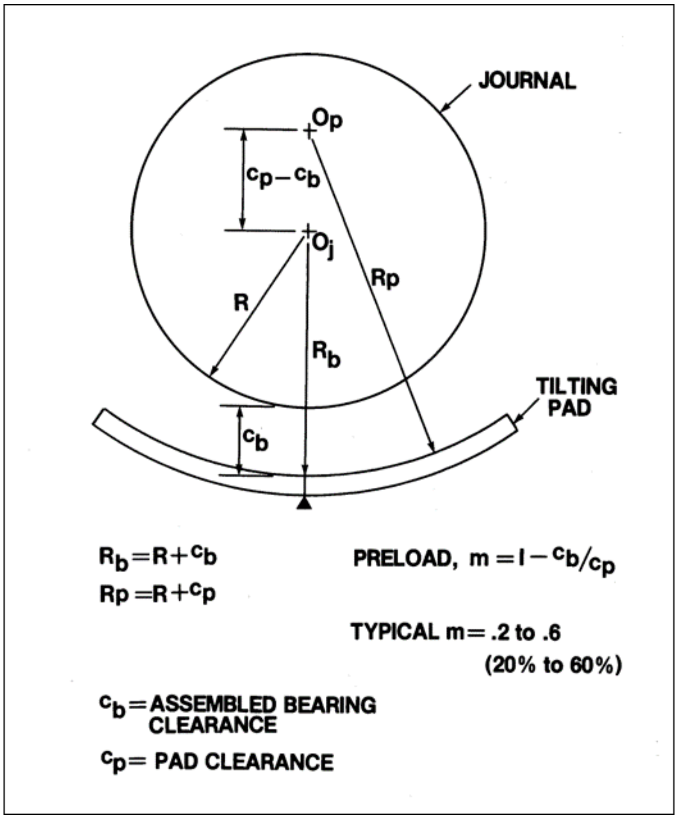


Figure H.4—Preload on Tilt Pad

Annex I
(normative)

Report Requirements for Torsional Analysis

(Report Requirements for Torsional Natural Frequency, Steady State Torsional Response, and Transient Torsional Response Analyses)

I.1 Standard Torsional Natural Frequency Report (for Systems That Comply with Separation Margins)

a) Torsional model:

1) sketch of torsional system;

2) clear identification of individual rotors and their associated inertias and coupling location(s);

3) shaft element length and diameters;

4) shaft material properties (material density, shear modulus of elasticity and strength properties);

5) identify inertia magnitude and location;

6) identify what each lumped inertia represents;

7) identify inertia of each body and the total for the train.

NOTE Inertia and stiffness are expected to be actual values and not referenced to a particular shaft in the train.

b) Coupling data:

1) stiffness and inertia;

2) description of shaft end model accounting for hub penetration.

c) Analysis methods:

1) list computer codes used in the analysis with a brief description of the type of code, e.g. finite element, Holzer, etc.

d) Torsional natural frequencies:

1) table of the torsional natural frequencies up to 2 times the highest rotor speed including separation margins.

e) Natural frequency mode shapes:

1) plots for all torsional natural frequencies that are less than or equal to 2 times the highest rotor speed.

f) Campbell diagram:

1) identify torsional natural frequencies;

2) identify operating speed range(s) with 10 % separation margin for train components;

3) identify torsional excitation frequencies.

NOTE A typical diagram is shown in Figure I.1.

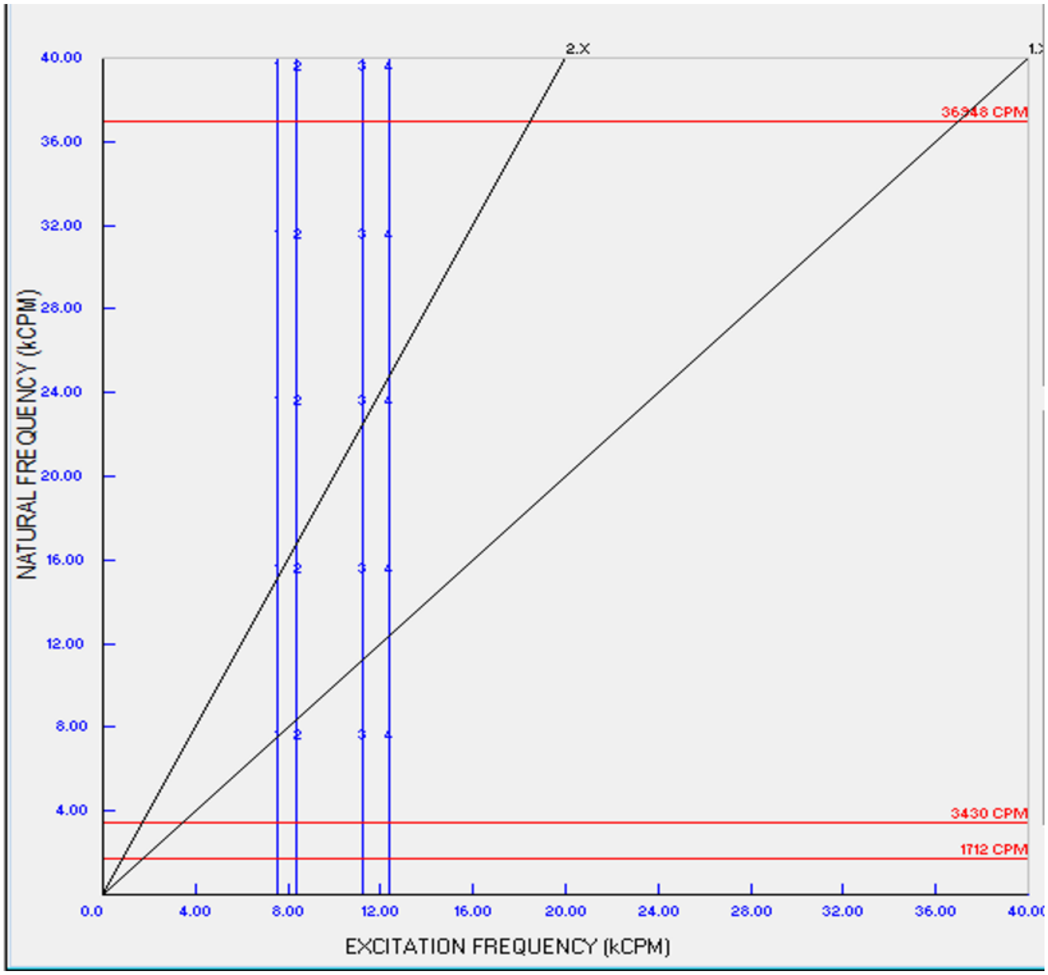


Figure I.1—Typical Campbell Diagram

I.2 Standard Torsional Natural Frequency Report [for Systems That Do Not Comply with Separation Margin(s)]

All items in I.1 above are required in addition to the following.

a) A statement of the potential torsional excitation mechanism(s), its location, magnitude, and frequency. The excitation mechanism shall be evaluated throughout the operating speed range.

b) Damping levels used in the analysis shall be stated.

c) The calculated peak torques for all couplings in the train shall be identified.

d) The calculated maximum shaft stress for each shaft shall be presented.

e) Shaft stress concentration factors applied shall be listed.

f) Statement of fatigue life acceptance criteria used and conformance.

I.3 Standard Transient Analysis of Generator Short Circuit, Synchronization, and Breaker Reclosure Report

The standard torsional natural frequency report associated with a conventional torsional natural frequency analysis shall be provided in accordance with I.1 and I.2 above as appropriate. In addition, the following shall be provided.

a) The torque magnitude and frequency associated with the short circuit faults, synchronization, or breaker reclosure conditions shall be identified.

b) The analysis shall identify the calculated peak torques in all rotors and coupling. The shaft stress at each of the peak torque locations shall be calculated and evaluated using criteria suitable for either high cycle or low cycle fatigue.

c) Damping levels and shaft material fatigue strength properties used shall be stated.

d) The calculated transient torque vs time for coupling and selected shaft sections shall be plotted. Calculated peak torques at the coupling shall be identified.

e) The transient stress vs time for selected shaft sections with low cycle fatigue identified shall be plotted.

f) A summary shall be included stating that the shafting stress does not exceed low cycle fatigue and that the coupling does not exceed its peak torque rating.

g) For breaker reclosure, the acceptance criteria shall be stated.

Annex J
(normative)

Procedure for the Verification of Residual Unbalance

J.1 General

This annex describes a procedure to verify residual unbalance in rotors by determining the calibration accuracy of the balancing equipment. Balancing machines may be configured to display the amount of rotor unbalance; however, the calibration can be in error. To determine the actual residual unbalance, a known amount of unbalance should be added using an appropriate procedure.

J.2 Residual Unbalance

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Residual unbalance shall be expressed in g-mm (g-in.).

J.3 Maximum Allowable Residual Unbalance

J.3.1 The maximum allowable residual unbalance, per plane, shall be calculated in accordance with Equation (J.1).

J.3.2 The static weight on each journal shall be determined from mass-elastic model. It should not be assumed that rotor weight is equally divided between the two journals.

NOTE There can be great discrepancies in the journal weight to the point of being very low (even negative on overhung rotors).

J.4 Residual Unbalance Check

J.4.1 General

J.4.1.1 When the balancing machine readings indicate that the rotor has been balanced within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine. Record and plot the indicated residual unbalance heavy spot of both planes on the Residual Unbalance Worksheet (one for each plane).

NOTE Due to the possibility of machine calibration errors, the residual unbalance check can be performed prior to final correction of the unbalance, typically after the placement of temporary weights.

J.4.1.2 To check the residual unbalance, a known trial weight equal to the multiplier from Table J.1 times the maximum allowable unbalance from Equation (J.1), is attached to the rotor at the same angular location as the indicated heavy spot. The check is run at each balance machine readout plane, and the readings in each plane are tabulated. This run is then repeated with the weight placed 180 ° opposite of the heavy spot at the same radius. The check is run at each balance machine readout plane, and the readings in each plane are tabulated.

Table J.1—Trial Weight Multiplier vs Maximum Continuous Speed (N_{mc})

Maximum Continuous Speed of Part/Assembly (N_{mc})	Trial Weight Multiplier
$N_{mc} \leq 7500$ rpm	1.5
$7500 \leq N_{mc} \leq 12{,}500$ rpm	2.0
$N_{mc} \geq 12{,}500$ rpm	2.5

J.4.2 Procedure

J.4.2.1 Select a trial weight and radius that will be equivalent to a trial weight multiplier times the maximum allowable residual unbalance as defined by Equation (J.1).

NOTE If U_r is 488.4 g-mm (19.2 g-in.) for a rotor with $N_{mc} \leq 7500$ rpm, the trial weight magnitude should equal 732.6 g-mm (28.8 g-in.).

In SI units (g-mm units):

$$U_r = 6350\frac{W}{N_{mc}}\left(for\ N_{mc} < 25,000\ rpm\right)$$
$$U_r = \frac{W}{3.937}\left(for\ N_{mc} \geq 25,000\ rpm\right) \quad \text{(J.1a)}$$

In USC units (g-in.) units:

$$U_r = 113.4\frac{W}{N_{mc}}\left(for\ N_{mc} < 25,000\ rpm\right)$$
$$U_r = \frac{W}{220.46}\left(for\ N_{mc} \geq 25,000\ rpm\right) \quad \text{(J.1b)}$$

where

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

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

N_{mc} is the maximum continuous operating speed, rpm;

W is the journal static load in kg (lbm), 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 (lbm).

J.4.2.2 At the heavy spot, add the first trial weight at the selected radius in J.4.2.1 to the first balance readout plane. Trial weight magnitude is a linear function with radial location. Every effort should be made to place the weight accurately, both radially and circumferentially.

J.4.2.3 Verify that the balancing machine readings are stable without faulty sensors or displays.

NOTE When the trial weight is added to the last known heavy spot, the first meter reading should easily exceed the balance tolerance in that plane. Little or no meter reading generally indicates that the rotor was either not balanced to the correct tolerance, the balancing machine was not sensitive enough, or that a balancing machine fault exists (i.e. a faulty pickup).

J.4.2.4 Remove the trial weight and rotate it to the second position (i.e. 180° from the initial trial weight position). All verification shall be performed using only one sensitivity range on the balance machine.

J.4.2.5 Record and plot the balancing machine unbalance amplitude and phase readout (heavy spot) on the Residual Unbalance Worksheet for the readout plane in question. If the indicated unbalance phase for the residual unbalance (from J.4.1.1) differs by more than 10° from the first trial weight phase angle or the second trial weight phase angle plus 180°, then the angular location of the trial weight should be adjusted to lessen the difference. Once the phase angle difference is less than 10°, the actual amount of residual unbalance (see Worksheets, Figure J.2 and Figure J.3) shall be calculated.

The difference in magnitudes of each trial weight run relative to the indicated unbalance should be within 20 %. If this is exceeded, weight placement and magnitude should be reviewed. A larger trial weight can be used with the value entered into the “User Selected Trial Weight,” otherwise this value should be zero.

NOTE 1 Not meeting this tolerance will generate errors in the calculated residual unbalance or indicate a problem with the balance machine.

NOTE 2 In Figure J.2, a larger trial weight was needed to enable the 2nd reading to be 180° different than the indicated reading (basically cross over the center of the plot). The larger trial weight (9 g) was inputted into the “User Selected Trial Weight” cell. This value of the trial weight “TW” is then used to calculate the “Actual Residual Unbalance.” For this example, the machine was determined to be reading $^1/_2$ of the actual unbalance.

J.4.2.6 Repeat the steps in accordance with J.4.2.1 to J.4.2.5 for each balance readout plane. If the specified maximum allowable residual unbalance has been exceeded in any balance machine readout plane when calculating the actual residual unbalance, the rotor shall be balanced more precisely and checked for compliance using the calibration factors determined above.

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

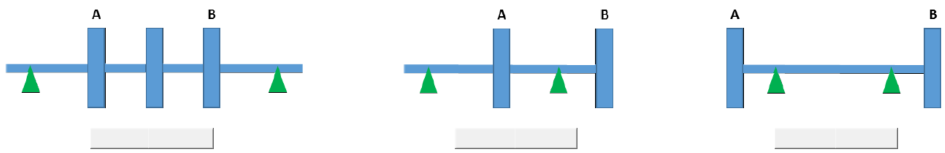
NOTE 1 This check ensures that time is not wasted, and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

NOTE 2 For large multistage rotors, the journal reactions can be considerably different from the case of a partially stacked to a completely stacked rotor.

Customer:
Job / Project Number:
OEM Equipment S/N:
Rotor Identification Number:
Repair Purchase Order Number:
Vendor Job Number:
Correction Plane (A or B) - see sketch:

Balancing Speed:		rpm		
Maximum Continuous Operating Speed:	Nmcs	rpm		
Static Journal Weight Closest to This Plane:	W	kg		lbm
W obtained from:		Rotordynamics		Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	R	mm		in

Balance Plain Description: End A End B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm Nmcs > 25000 rpm

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur: g-mm Unbalance @ Balance Plane: g

Customary Units: (USC expressed in grams)

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur: g-in Unbalance @ Balance Plane: g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um):

Recommended Trial Weight: g

User Selected Trial Weight: 0.00 g

Record Indicated Residual Unbalance (J.4.1.1) and the Indicated Unbalance with Trial Weight (J.4.2.5)

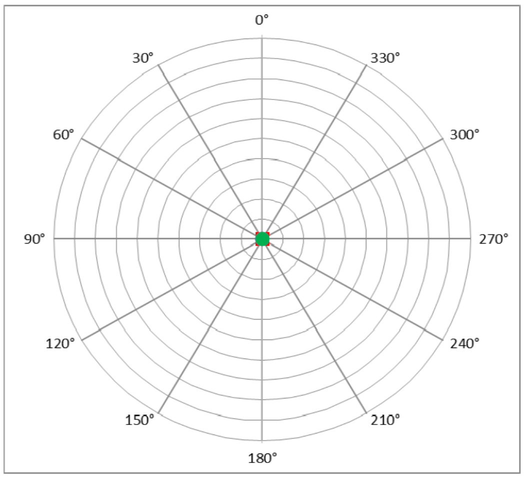
Test Data

Unbalance Readings		Magnitude grams (g)		Phase Angle degrees (°)	
A: Residual Unbalance (IR)*					
B: Unbalance w/ 1st Trial Weight (Mx)*					
C: Unbalance w/ 2nd Trial Weight (Mn)*					
	Y = Mx - Mn	0.00	Angle Diff |B-A| <10	0.00	
	Z = Mx + Mn	0.00	Angle Diff |C-A| <10	180.00	
Trial Weight Effect	R1 = Mx - IR	0.00	R2 = Mn + IR	0.00	
	R1/R2		R2/R1		
Uniformity Of Trial Weight Placement & Effect:		*Caution: Potential Inaccuracies*			
Angle diff < 10 and Magnitude ratio [0.8 < (R1/R2 & R2/R1) < 1.2]		*If cautioned, increase weight or adjust weight placement angle*			
		Metric (g-mm)		Customary (g-in)	
Residual Unbalance Reading (IR*R)					
Actual Residual Unbalance (AR=R*TW*Y/Z)					
Within Specification (AR < Ur)					

**** denotes indicated values***

- Indicated Residual Unbalance (red square)
- Indicated Unbalance w/ Trial Weight #1 (blue circle)
- Indicated Unbalance w/ Trial Weight #2 (green circle)

Indicates Input Required



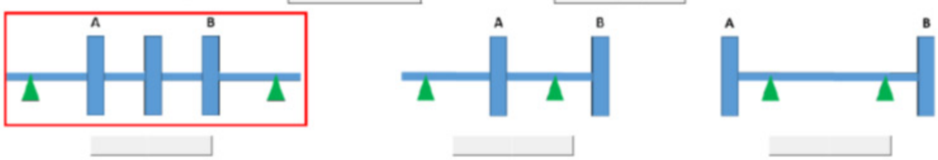
100% = #NUM! g

Figure J.1—Residual Unbalance Worksheet

Customer:	International Oil Company
Job / Project Number:	JN 2398-IRG-48
OEM Equipment S/N:	345-687
Rotor Identification Number:	C4784XL
Repair Purchase Order Number:	
Vendor Job Number:	12484-45985
Correction Plane (A or B) - see sketch:	Plane A

Balancing Speed:		400	rpm		
Maximum Continuous Operating Speed:	Nmcs	11000	rpm		
Static Journal Weight Closest to This Plane:	W	1300	kg		lbm
W obtained from:		Rotordynamics			Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	R	200	mm		in

Balance Plain Description: Thrust End A Coupling End B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm Nmcs > 25000 rpm

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur: 750.45 g-mm Unbalance @ Balance Plane: 3.75 g

Customary Units: (USC expressed in grams)

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur: g-in Unbalance @ Balance Plane: g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um): 2 Recommended Trial Weight: 7.50 g User Selected Trial Weight: 0.00 g

Record Indicated Residual Unbalance (J.4.1.1) and the Indicated Unbalance with Trial Weight (J.4.2.5)

Test Data

Unbalance Readings		Magnitude grams (g)		Phase Angle degrees (°)	
A: Residual Unbalance (IR)*		3.5		65	
B: Unbalance w/ 1st Trial Weight (Mx)*		10.7		62	
C: Unbalance w/ 2nd Trial Weight (Mn)*		4.2		247	
	Y = Mx - Mn	6.50	Angle Diff |B-A| <10	3.00	
	Z = Mx + Mn	14.90	Angle Diff |C-A| <10	2.00	
Trial Weight Effect	R1 = Mx - IR	7.20	R2 = Mn + IR	7.70	
	R1/R2	0.94	R2/R1	1.07	
Uniformity Of Trial Weight Placement & Effect:		Acceptable			
Angle diff < 10 and Magnitude ratio [0.8 < (R1/R2 & R2/R1) < 1.2]		*If coutioned, increase weight or adjust weight placement angle*			
		Metric (g-mm)		Customary (g-in)	
Residual Unbalance Reading (IR*R)		700.00			
Actual Residual Unbalance (AR=R*TW*Y/Z)		654.76			
Within Specification (AR < Ur)		YES			

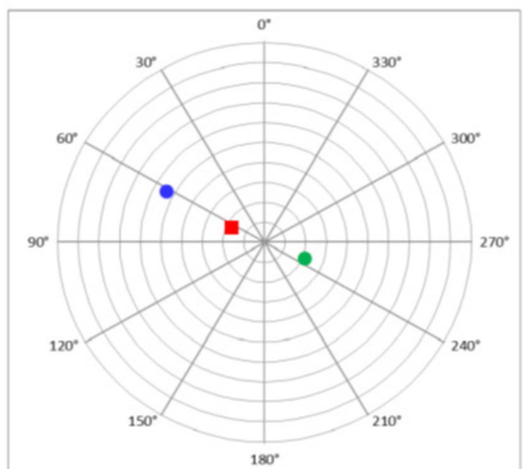
** denotes indicated values*

■ Indicated Residual Unbalance

● Indicated Unbalance w/ Trial Weight #1

● Indicated Unbalance w/ Trial Weight #2

Indicates Input Required



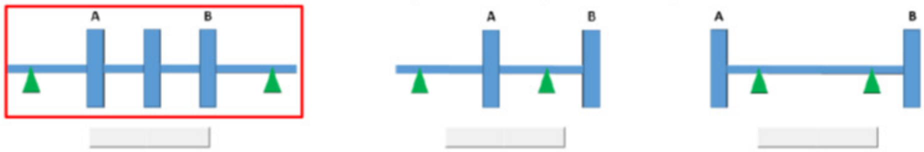
100% = 20 g

Figure J.2—Sample Residual Unbalance Worksheet for Left Plane (SI)

Customer:	US Oil Company
Job / Project Number:	JN 2398-IRG-48
OEM Equipment S/N:	345-687
Rotor Identification Number:	C4784XL
Repair Purchase Order Number:	
Vendor Job Number:	12484-45985
Correction Plane (A or B) - see sketch:	Plane B

Balancing Speed:		400	rpm		
Maximum Continuous Operating Speed:	Nmcs	11000	rpm		
Static Journal Weight Closest to This Plane:	W		kg	2866	lbm
W obtained from:		Rotordynamics			Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	R		mm	8	in

Balance Plain Description: Thrust End A Coupling End B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm Nmcs > 25000 rpm

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur: [ ] g-mm Unbalance @ Balance Plane: [ ] g

Customary Units: (USC expressed in grams)

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur: 29.55 g-in Unbalance @ Balance Plane: 3.69 g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um): 2

Recommended Trial Weight: 7.39 g

User Selected Trial Weight: 9.00 g

Record Indicated Residual Unbalance (J.4.1.1) and the Indicated Unbalance with Trial Weight (J.4.2.5)

Test Data

Unbalance Readings		Magnitude grams (g)	Phase Angle degrees (°)	
A: Residual Unbalance (IR)*		3.5	130	
B: Unbalance w/ 1st Trial Weight (Mx)*		8.2	135	
C: Unbalance w/ 2nd Trial Weight (Mn)*		1	312	
	Y = Mx - Mn	7.20	Angle Diff |B-A| <10	5.00
	Z = Mx + Mn	9.20	Angle Diff |C-A| <10	2.00
Trial Weight Effect	R1 = Mx - IR	4.70	R2 = Mn + IR	4.50
	R1/R2	1.04	R2/R1	0.96
Uniformity Of Trial Weight Placement & Effect:		Acceptable		
Angle diff < 10 and Magnitude ratio [0.8 < (R1/R2 & R2/R1) < 1.2]		*If cautioned, increase weight or adjust weight placement angle*		
		Metric (g-mm)	Customary (g-in)	
Residual Unbalance Reading (IR*R)			28.00	
Actual Residual Unbalance (AR=R*TW*Y/Z)			56.35	
Within Specification (AR < Ur)			NO	

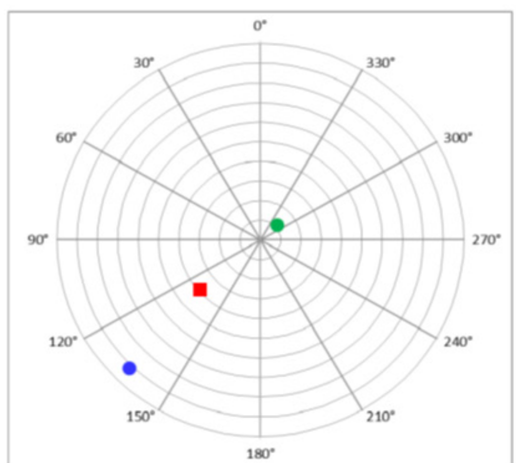
** denotes indicated values*

Indicated Residual Unbalance

Indicated Unbalance w/ Trial Weight #1

Indicated Unbalance w/ Trial Weight #2

Indicates Input Required



100% = 9 g

Figure J.3—Sample Residual Unbalance Worksheet for Right Plane (USC)

Annex K
(informative)

Typical Material Specifications

Table K.1 lists for information, some typical materials used for various steam 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 this annex, while they may not be typical, may or may not be acceptable for a particular application.

Table K.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 and 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)
Disks (built-up rotors only)	Carbon steel	ASTM A285, Grade C	Plate	316 (600)
	Ni-Cr-Mo steel, Q and 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)

Table K.1—Typical Material Specifications for Major Component Parts (Continued)

Part	Material	Specification	Form	Maximum Temperature °C (°F)
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 and 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 steel	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)
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 and 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)

Table K.1—Typical Material Specifications for Major Component Parts (Continued)

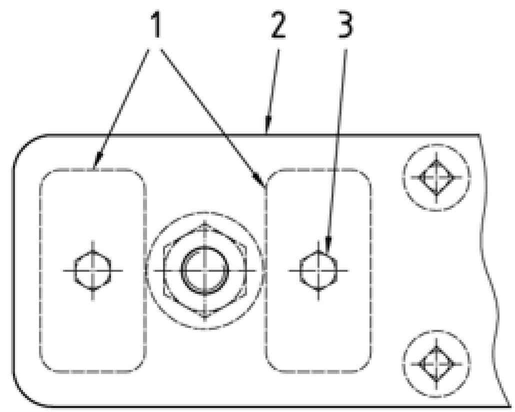
Part	Material	Specification	Form	Maximum Temperature °C (°F)
Fasteners	Cr-Mo alloy steel (AISI 4140)	ASTM A193, Grade B7 Bolts ASTM A194, Grade 7/7M Nuts		400 (750)
	Carbon steel	ASTM A307, Grade B Bolts ASTM A194, Grade 2H Nuts		400 (750)
	Cr-Mo-V steel	ASTM A193, Grade B16 Bolts ASTM A194, Grade 16 Nuts		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.

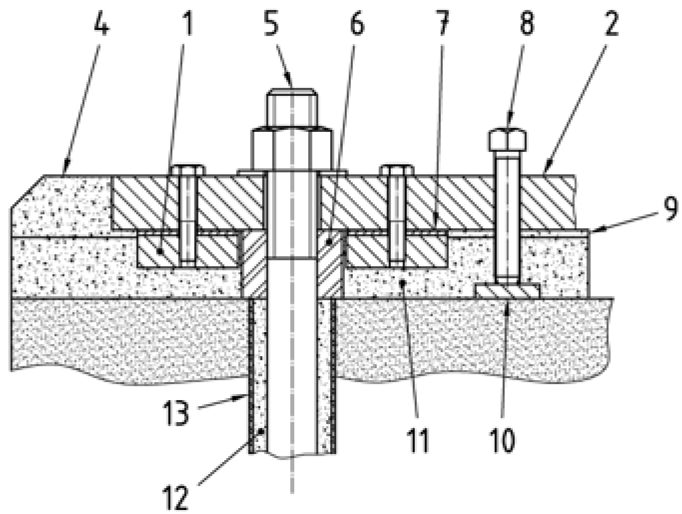
Annex L
(informative)

Mounting Plate Arrangements

See Figure L.1, Figure L.2, Figure L.3, and Figure L.4.



a) Top View of Foundation at Foundation Bolt

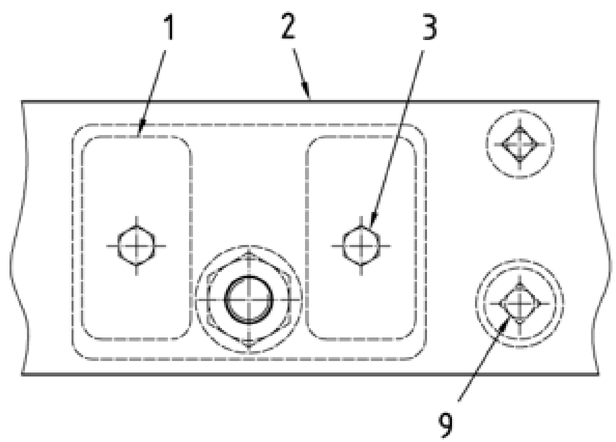


b) Cross Section of Foundation at Foundation Bolt

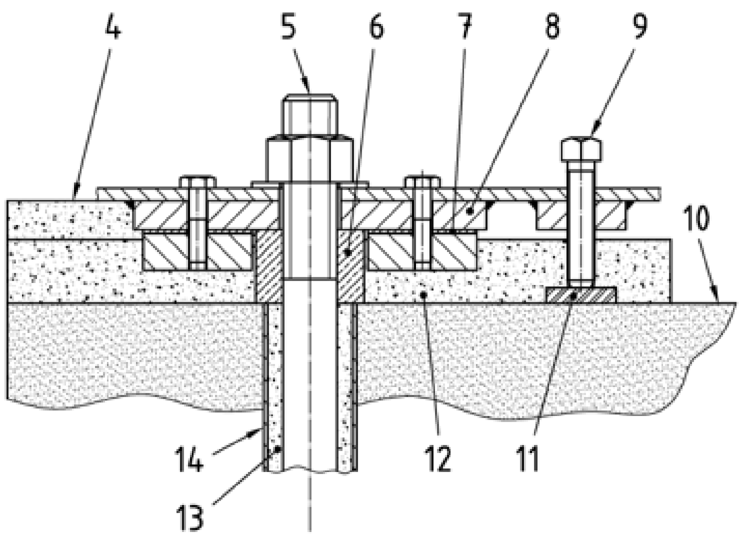
Key

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 L.1—Typical Mounting Plate Arrangement—Soleplate with Subplate



a) Top View of Foundation at Foundation Bolt

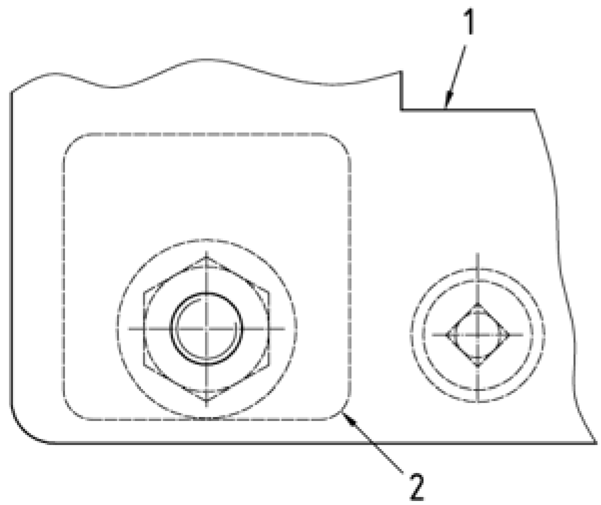


b) Cross Section of Foundation at Foundation Bolt

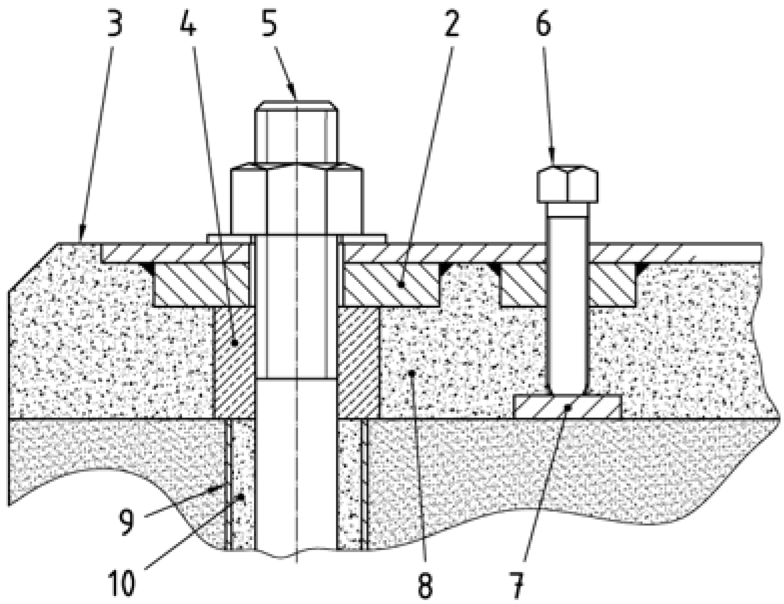
Key

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 L.2—Typical Mounting Plate Arrangement—Baseplate with Subplate



a) Top View of Foundation at Foundation Bolt

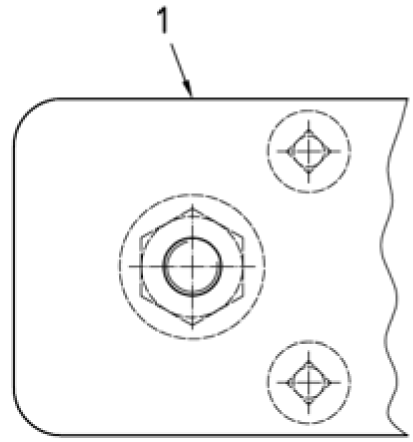


b) Cross Section of Foundation at Foundation Bolt

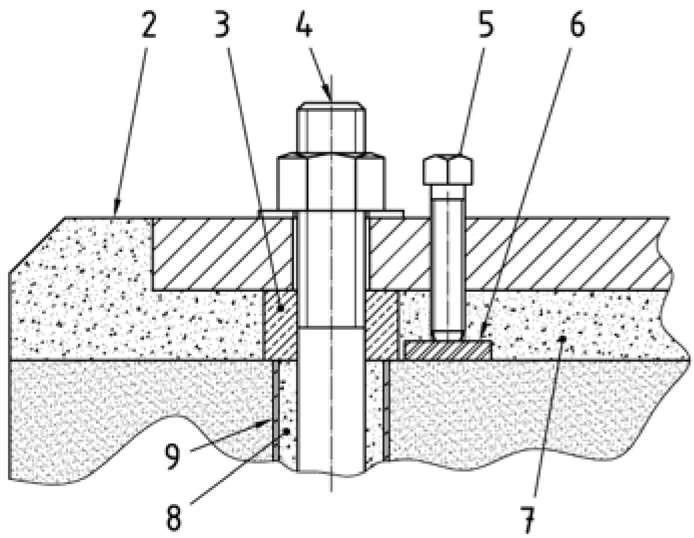
Key

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 L.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 L.4—Typical Mounting Plate Arrangement—Soleplate without Subplates

Annex M
(informative)

Inspector's Checklist

See Table M.1.

Table M.1—Inspector's Checklist

Item	Reference Subsection	Reviewed	Observed	Witnessed	Inspected by	Status
General						
Inspection records	8.2.1.1					
Final assembly maintenance and clearances	8.2.1.1 Item f)					
Surface and subsurface inspection	8.2.1.3 Item a)					
Material Inspection						
Material inspection certification/testing	8.2.2					
Mechanical Inspection						
Equipment feet (vertical and horizontal) jackscrews	6.2.13 7.6.1.4.1					
Foot/baseplate alignment shims	7.6.1.11					
Nozzle flange dimensions	6.4.9					
Casing openings—size/ finish	6.4.1 6.4.9					
Rotor identification	6.6.2.3					
Number of teeth for governor and overspeed shutdown system wheel	6.6.4 7.7.2.1.12					
Shaft finishes	6.6.1.1					
Shaft electrical and mechanical runout	6.6.1.1 6.8.7.9					
Shaft magnetic flux density	8.2.2.4					
Coupling shaft end design	6.6.1.2					
Rotor balance (balance machine residual)	6.8.7					
Rotation arrow/nameplate data and units	6.12.2 6.12.3					
Mounting surfaces coated	7.6.1.10 Item d)					
Mounting surfaces primed	7.6.1.7.1					
Oil system cleanliness	8.2.3.2					
Equipment cleanliness	8.2.3.3					
Material hardness	8.2.3.4					
Mechanical Running Test						

Table M.1—Inspector's Checklist (Continued)

Item	Reference Subsection	Reviewed	Observed	Witnessed	Inspected by	Status
Contract shaft seals and bearings	8.3.3.1.1					
Oil flows, pressure, and temperature as specified	8.3.3.1.2					
No leaks observed	8.3.3.1.4					
Protective devices operational	8.3.3.1.5					
Control devices operational	8.3.3.1.5					
Control instrumentation used	8.3.3.1.8					
Control system functional at specified speeds	8.3.3.2					
Four-hour test complete	8.3.3.2.5					
Recordings complete	8.3.3.3.6					
Bearing inspection after test satisfactory	8.3.3.4					
Spare rotor fit and run	8.3.3.3.8					
Overspeed shutdown systems test	8.3.4					
Trip valve test	8.3.5					
Optional Tests						
Performance test	8.3.6.1					
Complete unit test	8.3.6.2					
Auxiliary equipment test	8.3.6.3					
Post-test casing internal inspection	8.3.6.4					
Field overspeed shutdown systems response test	8.3.6.5					
Spare parts test	8.3.6.6					
Inspection of hub/shaft fit for hydraulically mounted couplings	8.3.6.7					
Governor system response test under load	8.3.6.8					
Sound level test	8.3.6.9					
Preparation for Shipment						
Preparation complete	8.4.1					
Paint	8.4.4					
Rust preventative (exterior and interior)	8.4.5 8.4.6					

Table M.1—Inspector's Checklist (Continued)

Item	Reference Subsection	Reviewed	Observed	Witnessed	Inspected by	Status
Tagging complete	8.4.12 8.4.23					
Installation instructions shipped	8.4.6					
Special tools complete	7.9.2					
Spare parts complete	O.3.4					
Studs installed	6.4.10					

Annex N
(informative)

Typical Inspection of Components

See Table N.1.

Table N.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>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></td><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>
<tr><td colspan="7">[a] Per lot. See 6.11.1.11 for positive material identification (PMI) testing of turbine components.
[b] Typical surface magnetic particle inspection.
[c] The details of testing shall be agreed between the purchaser and the vendor.
[d] Where practical on larger components.</td></tr>
</table>

Annex O
(informative)

Contract Documents and Engineering Design Data

O.1 Introduction

If specified by the purchaser in 9.2, the contract documents and engineering design data shall be supplied by the vendor, as listed in this annex.

O.1.1 The following data shall be identified on transmittal (cover) letters, title pages, and correspondence:

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

b) job/project number;

c) equipment item number and service name;

d) inquiry or purchase order number;

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

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

O.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, identification data specified in O.1.1, revision number, date and title. Similar information shall be provided on all other documents including subvendor items.

O.2 Proposals

O.2.1 General

O.2.1.1 The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents.

O.2.1.2 The proposal shall include, as a minimum, the data specified in O.2.2 through O.2.5, and a specific statement that the equipment and all its components and auxiliaries are in strict accordance with this standard.

O.2.1.3 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.

O.2.1.4 The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs.

O.2.1.5 All correspondence shall be clearly identified in accordance with O.1.1.

O.2.2 Drawings

O.2.2.1 The drawings indicated on the VDDR form (see Annex G) shall be included in the proposal. As a minimum, the following data shall be included:

a) a 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 electrical systems;

d) bill of material;

e) sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries; this information may be included on the drawings specified in O.2.2.1 a).

O.2.2.2 If "typical" drawings, schematics, and bills of material are used, they shall be marked up to show the weight and dimension data to reflect the actual equipment and scope proposed.

O.2.3 Technical Data for Proposal

O.2.3.1 All technical data shall be provided in units of measurement according to the purchase order. If needed, the technical data in alternate units may be included in parentheses.

O.2.3.2 The following data shall be included in the proposal:

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

b) predicted noise data (see 6.1.8);

c) VDDR form (or equivalent listing), indicating the schedule according to which the vendor agrees to transmit all the data specified;

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

e) list of major wearing components, showing any interchangeability with the owner's existing turbine units;

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

g) list of the special tools furnished for maintenance;

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

i) 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;

j) description of any optional or additional tests and inspection procedures for materials, in accordance with 8.3.6;

k) description of any special requirements, whether specified in the purchaser's inquiry or as outlined in 6.11.1.2;

l) 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;

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

n) a list of any components that is construed as being of alternative design, hence requiring purchaser's acceptance;

o) components designed for finite life (see 6.1.2);

p) the expected output power at normal steam conditions and rated speed with governor control valves fully open;

q) 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);

r) a list of all relief valves in accordance with 7.2, including size and set pressure-relief valves furnished by the vendor shall also be specified, with valve manufacturer and model data provided;

s) the types of fasteners (e.g. SI or USC) used in equipment, including auxiliaries, in the vendor's scope of supply;

t) 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 meets the technical requirements in a satisfactory and reliable manner, for the purchaser's approval;

u) upper limit of steam flow velocity values used in the sizing of turbine inlet, exhaust and extraction and induction flanges (if applicable) at rated power and rated steam conditions.

O.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.

O.2.5 Optional Tests

The vendor shall furnish an outline of the procedures to be used for each of the special or optional tests that have been specified by the purchaser or proposed by the vendor.

O.3 Engineering Design Data

O.3.1 General

O.3.1.1 Engineering data shall be furnished by the vendor in accordance with the agreed VDDR form.

NOTE Typical VDDR form can be modified by the purchaser to match the specific inquiry requirements.

O.3.1.2 The purchaser shall review the vendor's data upon receipt; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed in writing. After the data have been reviewed and accepted, the vendor shall furnish certified copies in the quantities specified.

O.3.1.3 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 respect to the VDDR form in the purchase order.

O.3.2 Drawings and Technical Data

O.3.2.1 The drawings and data furnished by the vendor shall contain sufficient information in addition to the manuals specified in O.3.5, to allow the purchaser to properly install, operate, and maintain the equipment covered by the purchase order.

O.3.2.2 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 O.3.1.1), and shall satisfy the applicable detailed descriptions in Annex G.

O.3.2.3 Material certifications shall be provided for the turbine rotor shaft, buckets, shrouds, and major casing components.

O.3.2.4 PMI records shall be provided if PMI is specified for applicable alloy steel components.

O.3.3 Progress Reports

The vendor shall submit progress reports to the purchaser at intervals specified which shall, as a minimum, include the following:

a) overall progress summary;

b) status of engineering;

c) status of document submittals;

d) status of major suborders;

e) updated production schedule;

f) inspection/testing highlights for the month;

g) any pending issues.

O.3.4 Parts Lists and Recommended Spares

O.3.4.1 The vendor shall submit complete parts lists for all equipment and accessories supplied.

O.3.4.2 These lists shall include part names, manufacturers' unique part numbers and materials of construction (identified by applicable international standards).

O.3.4.3 Each part shall be completely identified and shown on appropriate cross-sectional, assembly-type cutaway or exploded-view isometric drawings.

O.3.4.4 Interchangeable parts shall be identified as such.

O.3.4.5 Parts that have been modified from standard dimensions or finished to satisfy specific performance requirements shall be uniquely identified by part number.

O.3.4.6 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 shall include spare parts recommendations of subvendors that were not available for inclusion in the vendor's original proposal.

O.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

O.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 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 O.1.1, an index sheet, and a complete list of enclosed drawings by title and drawing number.

O.3.5.1.1 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.

O.3.5.1.2 If the order covers more than one turbine, all turbines that are not identical require separate documentation.

O.3.5.1.3 A draft manual(s) shall be issued to purchaser 8 weeks prior to mechanical testing for review and comments.

O.3.5.1.4 Refer to the agreed VDDR form for number of copies. Hard copies as well as electronic copies shall be provided as described on VDDR form.

O.3.5.2 Installation Manual

O.3.5.2.1 All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions.

O.3.5.2.2 This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging provisions and procedures, and all installation data.

O.3.5.2.3 All drawings and data specified in O.2.2 and O.2.3 that are pertinent to proper installation shall be included as part of this manual [see also description of line Item pp) in Annex G].

O.3.5.2.4 One extra manual, over and above the specified quantity, shall be included with the first equipment shipped.

O.3.5.2.5 All recommended receiving and storage procedures shall be included.

NOTE Refer to API 686 for data needed for installation.

O.3.5.3 Operating and Maintenance Manual

A manual containing all required operating and maintenance instructions shall be supplied at shipment. In addition to covering operation at all specified process conditions, this manual shall also contain separate sections covering operation under any specified extreme environmental conditions [see description of line Item pp) in Annex G].

O.3.5.4 Technical Data Manual

If specified, the vendor shall provide the purchaser with a technical data manual at shipment [see description of line Item vv) in Annex G for minimum requirements of this manual].

Bibliography

[1] API Recommended Practice 578, *Material Verification Program for New and Existing Alloy Piping Systems, First Edition, 1999*

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[3] API Recommended Practice 687, *Rotor Repair, First Edition 2001 (Reaffirmed 2009)*

[4] AMS-S-13165,[12] *Shot Peening of Metal Parts, superseded by SAE AMS 2430*

[5] ASME B18.12-2001, *Glossary of Terms for Mechanical Fasteners*

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[10] ASTM A536, *Standard Specification for Ductile Iron Castings*

[11] ASTM B127, *Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip*

[12] ASTM E572, *Standard Test Method for Analysis of Stainless and Alloy Steels by Wavelength Dispersive X-Ray Fluorescence Spectrometry*

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[14] ISO 7005-1, *Pipe flanges—Part 1: Steel flanges for industrial and general service piping systems*

[15] ISO 10494, *Turbines and turbine sets—Measurement of emitted airborne noise—Engineering/survey method*

[16] ISO 13732-1, *Ergonomics of the thermal environment-methods for the assessment of human responses to contact with surfaces*

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[12] SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

[13] U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue NW, Washington, DC 20210, www.osha.gov.

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

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