INTERNATIONAL STANDARD

ISO 10437

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Petroleum, petrochemical and natural gas industries — Steam turbines — Special-purpose applications

Industries du pétrole, de la pétrochimie et du gaz naturel — Turbines à vapeur — Usage spécial

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10437 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

This second edition cancels and replaces the first edition (ISO 10437:1993), which has been technically revised.

Introduction

This International Standard is based on API Std 612, fourth edition, June 1995.

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

This International Standard requires the purchaser to specify certain details and features.

A bullet (●) at the beginning of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information or decision should be indicated on the data sheets; otherwise it should be stated in the quotation request (inquiry) or in the order.

In this International Standard, where practical, US Customary units have been included in brackets for information.

Petroleum, petrochemical and natural gas industries — Steam turbines — Special-purpose applications

1 Scope

This International Standard specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of steam turbines for special-purpose applications. It also covers the related lube-oil systems, instrumentation, control systems and auxiliary equipment. It is not applicable to general-purpose steam turbines, which are covered in ISO 10436.

NOTE For the purpose of this provision, API Std 611 is equivalent to ISO 10436.

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.

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

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

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

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

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

ISO 1940-1, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance*

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

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

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

ISO 8068, *Petroleum products and lubricants — Petroleum lubricating oils for turbines (categories ISO-L-TSA and ISO-L-TGA) — Specifications*

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

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

ISO 10438 (all parts)[1] , *Petroleum and natural gas industries — Lubrication, shaft sealing and control oil systems for special-purpose applications*.

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

ISO 13691, *Petroleum and natural gas industries — High-speed special-purpose gear units*

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

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

IEC 60072, *Dimensions and output series for rotating electrical machines*

IEC 60079, *Electrical apparatus for explosive atmospheres*

IEC 60953, *Rules for steam turbine thermal acceptance tests*

EN 287, *Approval testing of welders — Fusion welding*[2]

EN 288, *Specification and approval of welding procedures for metallic materials*

API RP 520 PT I, *Sizing, selection, and installation of pressure-relieving systems in refineries, Part I — Sizing and selection.*[3]

API RP 520 PT II, *Sizing, selection, and installation of pressure-relieving systems in refineries, Part II — Installation*

API Std 526, *Flanged steel pressure relief valves*

API Std 613, *Special-purpose gear units for petroleum, chemical and gas industry services*

API Std 670, *Machine protection systems*

API Std 671, *Special-purpose couplings for petroleum, chemical and gas industry services*

API RP 686 (First edition, April 1996), *Recommended Practices for machinery installation and installation design*

ASME, *Boiler and pressure vessel code, Section V — Nondestructive examination.*[4]

ASME, *Boiler and pressure vessel code, Section VIII — Pressure vessels*

ASME, *Boiler and pressure vessel code, Section IX — Qualification standard for welding and brazing procedures, welders, brazers, and welding and brazing operators*

ASME B1.1, *Unified screw threads (UN and UNR Thread Form)*

ASME B16.1, *Cast iron pipe flanges and flanged fittings, Class 25, 125 and 250*

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1) To be published.

2) Comité Européen de Normalisation, 36, rue de Stassart, B-1050 Brussels, Belgium.

3) American Petroleum Institute, Publications and Distribution Section, 1220 L Street Northwest , Washington DC 20005, USA.

4) ASME International, 3 Park Avenue, New York, NY 10016-5990, USA.

ASME B16.5, *Pipe flanges and flanged fittings, NPS 1/2 through NPS 24*

ASME B16.11, *Forged fittings, socket-welding and threaded*

ASME B16.42, *Ductile iron pipe flanges and flanged fittings, classes 150 and 300*

ASME B16.47, *Large diameter steel flanges NPS 26 through NPS 60*

ASME B17.1, *Keys and keyseats*

ASME PTC 6, *Performance test code 6 on steam turbines*

ASME PTC 20.2, *Overspeed trip systems for steam turbine-generator units*

ASTM A 194, *Standard specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both*[5]

ASTM A 247, *Standard test method for evaluating the microstructure of graphite in iron castings*

ASTM A 278, *Standard specification for gray iron castings for pressure-containing parts for temperatures up to 650 °F (350 °C)*

ASTM A 307, *Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength*

ASTM A 395, *Standard specification for ferritic ductile iron pressure-retaining castings for use at elevated temperatures*

ASTM A 418, *Standard test method for ultrasonic examination of turbine and generator steel rotor forgings*

ASTM A 472, *Standard test method for heat stability of steam turbine shafts and rotor forgings*

ASTM A 536, *Standard specification for ductile iron castings*

AWS D1.1, *Structural welding code — Steel*[6]

NEMA SM 23, *Steam turbines for mechanical drive service*.[7]

NFPA 70, *National electrical code*.[8]

NACE MR0175, *Sulfide stress cracking resistant metallic materials for oilfield equipment*.[9]

SSPC-SP6/NACE No. 3, *Commercial blast cleaning*.[10]

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5) American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

6) American Welding Society, 550 NW Le Jeune Road, PO Box 351040, Miami, FL 33130, USA.

7) National Electrical Manufacturers Association, 1300 N 17th Street; Suite 1847, Rosslyn, VA 22209, USA.

8) National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA.

9) NACE International, 1440 South Creek Drive, Houston, TX 77084, USA.

10) SSPC: The Society for Protective Coatings, 40 24th Street 6th floor, Pittsburgh, PA 15222-4656, USA.

3 Terms and definitions

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

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

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

3.3
axially split
split with the principal joint parallel to the shaft centreline

3.4
control mechanism
all of the equipment between the speed governor and the governor-controlled valve(s) (such as linkages, pilot valves, power servos, and so forth)

3.5
critical speed
shaft rotational speed at which the rotor-bearing-support system is in a state of resonance

3.6
design
equipment manufacturer's description of various parameters relevant to the equipment

NOTE This terminology is for use only by the equipment manufacturer and is not intended to appear in the purchaser's specifications.

3.7
fail safe system
system which causes the equipment to revert to a permanently safe condition (shutdown and/or depressurized) in the event of a component failure or failure of the energy supply to the system

3.8
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.

3.9
gauge board
bracket or plate used to support and display gauges, switches, and other instruments

NOTE A gauge board is open and not enclosed.

3.10
general-purpose turbines
horizontal or vertical turbines used to drive equipment that is usually spared, is relatively small in size (power), or is in non-critical service

NOTE General-purpose steam turbines are intended for applications where the inlet gauge pressure does not exceed 4 800 kPa (48 bar) (700 psi) and the inlet temperature does not exceed 400 °C (750 °F), and where the speed does not exceed 6 000 r/min.

3.11
governor-controlled valve
device that controls the flow of steam into or out of the turbine in response to the speed governor

3.12
hold-down bolts
mounting bolts
bolts that hold the equipment to the mounting plate or plates

3.13
hydrodynamic bearings
bearings that use the principles of hydrodynamic lubrication

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

3.14
local
⟨device⟩ mounted on or near the equipment or console

3.15
maximum allowable speed
highest speed at which the manufacturer's design permits continuous operation

3.16
maximum allowable temperature
maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at any specified operating conditions

3.17
maximum allowable working pressure
maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the maximum allowable temperature

3.18
maximum continuous speed
highest speed at which the turbine, as built and tested, is capable of continuous operation, at any of the specified steam conditions

3.19
maximum exhaust casing pressure
highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions

NOTE The turbine casing is subjected to the maximum temperature and pressure under these conditions.

3.20
maximum exhaust pressure
highest exhaust steam pressure at which the turbine is required to operate continuously

3.21
maximum inlet pressure and temperature
highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously

3.22
maximum sealing pressure
highest pressure the seals are required to seal during any specified static or operating conditions and during startup and shutdown

3.23
minimum allowable speed
lowest speed at which the manufacturer's design permits continuous operation

3.24
minimum exhaust pressure
lowest exhaust steam pressure at which the turbine is required to operate continuously

3.25
minimum inlet pressure and temperature
lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously

3.26
normal operating point
point at which usual operation is expected and optimum efficiency is desired

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

3.27
observed
test or inspection for which the purchaser requires notification of the timing and may wish to attend

NOTE This is not a hold point. The inspection or test is performed as scheduled, and if the purchaser or the purchaser's representative is not present, the vendor proceeds to the next step.

3.28
owner
final recipient of the equipment who may delegate another agent as the purchaser of the equipment

3.29
panel
enclosure used to mount, display and protect gauges, switches and other instruments

3.30
potential maximum power
approximate maximum power to which the turbine can be uprated at the specified normal speed and steam conditions when it is furnished with suitable (that is, larger or additional) nozzles and, possibly, with a larger governor-controlled valve or valves

3.31
pressure casing
composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts

3.32
purchaser
agency that issues the order and specification to the vendor

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

3.33
radially split
split with the principal joint perpendicular to the shaft centreline

3.34
rated power
greatest turbine power specified and its corresponding speed; it includes all the margin required by the specifications of the driven equipment

3.35
rated speed
100 % speed
highest rotational speed required to meet any of the specified operating conditions

3.36
relief valve set pressure
pressure at which a relief valve starts to lift

3.37
remote
⟨device⟩ located away from the equipment or console, typically in a control room

3.38
separation margin
margin between a critical speed and the nearest required operating speed

3.39
shutdown set point
preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required

3.40
slow roll
speed recommended by the vendor (typically 400 r/min to 500 r/min) for warm-up and initial check of equipment integrity prior to full operation

3.41
special-purpose turbines
horizontal turbines used to drive equipment that are usually not spared and are used in uninterrupted continuous operation in critical service

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

3.42
special tool
tool which is not a commercially available catalogue item

3.43
standby service
normally idle, or idling, piece of equipment that is capable of immediate automatic or manual startup and continuous operation

3.44
steam rate
quantity of steam required by the turbine per unit of power output measured at the output shaft of the turbine

3.45
turbine manufacturer
company that designs, manufactures, tests and provides service support for the turbine

3.46
trip speed
rotational speed at which the independent overspeed shutdown system operates to shut down a turbine

3.47
unit responsibility
responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order

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

3.48
vendor
supplier
agency that supplies the equipment in response to the order

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

3.49
witnessed
inspection or test that the purchaser attends

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

4 Dimensions

● Drawings and maintenance dimensions shall be in SI units or United States Customary (USC) units. Use of an ISO datasheet indicates that SI units shall be used. Use of a USC datasheet indicates that USC units shall be used. Typical datasheets in both systems of units are given in Annex A.

5 Statutory requirements

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

6 Basic design

6.1 General

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

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

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

6.1.3 The vendor who has unit responsibility shall assure that all subvendors comply with the requirements of this International Standard.

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

● **6.1.5** The purchaser shall specify the purity of steam available.

NOTE IEC 60045-1 and NEMA SM 23 contain recommendations for steam purity levels.

6.1.6 Turbines shall be capable of the following:

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

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

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

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

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

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

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

g) operation with variations from rated steam conditions and steam purity levels recommended in IEC 60045-1 or NEMA SM 23;

h) operation uncoupled with maximum inlet steam conditions.

Governing instability and high acceleration rates may occur and require action such as throttling of inlet pressure. Care should be taken when operating uncoupled or no load for generator sets. Consideration should be given to the high exhaust and extraction steam temperatures that would result during light or no-load operation.

6.1.7 Equipment shall be designed to run to the trip speed without damage. The turbine trip speed shall be 110 % of maximum continuous speed, normally 116 % of rated speed.

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

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

6.1.9 Many factors may 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 one or more of 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;

c) shaft alignment at operating temperature.

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

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

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

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

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

Table 1 — Design criteria and specifications for cooling water systems

Criteria	SI units	US Customary units
Water velocity over heat exchanger surfaces	1,5 m/s to 2,5 m/s	5 ft/s to 8 ft/s
Maximum allowable working pressure, gauge	700 kPa	100 psi (7 bar)
Test pressure (1,5 MAWP), gauge	1 050 kPa	150 psi (10,5 bar)
Maximum pressure drop	100 kPa	15 psi (1 bar)
Maximum inlet temperature	32 °C	90 °F
Maximum outlet temperature	49 °C	120 °F
Maximum temperature rise	17 K	30 °R
Minimum temperature rise	11 K	20 °R
Fouling factor on water side	0,32 m^2·K/kW	0,002 hr-ft^2-°F/Btu
Shell corrosion allowance	3 mm	1/8 in
NOTE The criterion for velocity over heat exchange surface is intended to minimize water side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water.		

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

● **6.1.15** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment. The vendor shall provide details of any special measures taken to achieve the stated levels.

● **6.1.16** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable sections of IEC 60079 or NFPA 70, Articles 500, 501, 502, and 504, as well as any local codes specified (and, if requested by the vendor, furnished) by the purchaser.

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

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

6.1.19 Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this International Standard.

6.2 Nameplates and rotation arrows

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

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

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

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

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

b) vendor's name;

c) serial number;

d) size and type;

e) rated power and speed;

f) all lateral critical speeds less than trip speed;

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

h) maximum continuous speed;

i) trip speed (see 3.46);

j) normal and maximum inlet steam temperature and pressure;

k) normal and maximum exhaust steam pressure;

l) number of teeth in the multi-toothed surface provided for speed sensing (see 8.4).

6.2.5 Any 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”.

● **6.2.6** The purchaser shall specify the units to be shown on the nameplate.

7 Casings

7.1 Pressure casings

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

7.1.2 The tensile stress used in the design of the pressure casing for any material shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature, and, for castings, multiplied by the appropriate casting factor as shown in Table 2. The manufacturer shall state the source of the material properties, such as ASTM, as well as the casting factors applied in his/her proposal.

NOTE For bolting, the allowable tensile stress is used to determine the total bolting area based on pressure load or gasket preload. It is recognized that to provide the initial load required to obtain a reliable bolted joint, the bolting will be tightened to produce a tensile stress higher than the design tensile stress. Values in the range of 0,7 times yield are common.

Table 2 — 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

7.1.3 The maximum allowable working pressure(s) of the casing shall be at least equal to the specified relief valve set point(s). For condensing turbines, the exhaust casing shall be designed for both full vacuum and for a maximum allowable working gauge pressure of at least 70 kPa (0,7 bar) (10 psi).

Normally, a full-capacity safety relief valve is required in the exhaust piping between each exhaust connection and exhaust block valve to prevent overpressure and possible rupture of the turbine casing.

7.1.4 The vendor shall define the physical limits and the maximum allowable working pressure of the turbine casing and of each part of turbine casings designed for more than one maximum allowable pressure level (split-pressure-level casings).

7.1.5 The turbine casing shall be axially split. Turbine casings may also be split radially between high-pressure and low-pressure sections.

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

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

7.1.8 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change in the relative position of the shaft ends caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 µm (0,002 in) (see 7.4).

NOTE This clause does not apply to thermal growth.

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

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

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

7.1.12 The steam chest and casing shall be provided with connections to ensure complete drainage. Drain connections shall be DN25 (NPS 1) minimum size.

7.1.13 The use of threaded holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to any allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1,5 times the stud diameter. Through bolting is preferred in areas of the casing where the temperature may exceed 410 °C (775 °F).

7.1.14 Studded connections shall be furnished with studs installed. The first 1,5 threads at both ends of each stud shall be removed.

7.1.15 Bolting shall be furnished as follows.

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

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

c) Studs or through bolts shall be used instead of cap screws on all other joints, except where hexagonal head cap screws are essential for assembly purposes and have been approved by the purchaser.

d) The manufacturer's marking, in accordance with the appropriate standard (e.g. ASTM), shall be located on all fasteners 6 mm (1/4 in) and larger (excluding washers and headless set screws). For studs, the marking shall be located on the nut end of the exposed stud.

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

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

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

7.1.16 Mounting surfaces shall meet the following criteria.

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

b) The mounting surfaces in one plane shall be machined such that no point on any surface deviates from the common plane by more than 50 µm (0,002 in).

c) The different mounting planes shall be parallel to each other within 1 in 1 000, in any direction.

d) The upper surfaces shall be machined or spot-faced (to a diameter three times that of the hole), parallel to the mounting surface.

7.1.17 Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces and shall be 15 mm (0,6 in) larger in diameter than the hold-down bolt.

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

7.2 Casing connections

● **7.2.1** The purchaser shall specify the orientation of the main inlet and outlet steam connections. All connections shall be suitable for the maximum allowable working pressure(s) of the casing. Flanged connections shall be integral with the casing or, for casings of weldable material, may be formed by a socket-welded or butt-welded pipe nipple or transition piece, and shall terminate with a weld-neck or socket-weld flange.

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

7.2.3 Casing openings for piping connections shall be at least DN 20 (NPS 3/4) and shall be flanged or machined and studded. For casings of non-weldable materials, and where flanged or machined and studded openings are impractical, threaded openings in DN 20 (NPS 3/4) to DN 40 (NPS 1½) are permissible. Connections to these threaded openings shall be installed as follows.

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

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

c) Threaded openings and bosses for tapered pipe threads shall conform to ASME B16.5.

d) Pipe threads shall be tapered threads conforming to ISO 7-1.

NOTE For the purpose of this provision, ASME B1.20.1 is equivalent to ISO 7-1.

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

7.2.4 Pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller, and a minimum of Schedule 80 for DN 40 (NPS 1½). Bracing or reinforcement is required when nipples longer than 150 mm (6 in) are necessary.

7.2.5 Sizes DN 32, DN 65, DN 90, DN 125, DN 175 and DN 225 (NPS 1 1/4, 2 1/2, 3 1/2, 5, 7, and 9) shall not be used.

7.2.6 For non-weldable casing materials, threaded openings not required to be connected to piping shall be plugged with solid, round-head steel plugs in accordance with ASME B16.11, unless otherwise specified. Plugs that may later require removal shall be of a corrosion-resistant material. Plastic plugs are not permitted.

7.2.7 Flanges shall conform to the following.

a) Cast iron flanges shall be flat faced and conform to the dimensional requirements of ISO 7005-2 or ASME B16.1 or ASME 16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (8 NPS) and smaller. Gray cast iron shall not be used.

b) Steel flanges shall conform to dimensional requirements of ISO 7005-1 or ASME B16.5 or B16.47.

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

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

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

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

g) Vertical nozzles shall have flanges parallel with the horizontal plane within 0,5°. Horizontal nozzles shall have flanges parallel with the vertical plane within 0,5°. Studs or bolt holes shall straddle centrelines parallel to the main axes of the equipment.

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

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

7.3 Internal stationary components

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

7.3.2 All other stationary blading shall be mounted in replaceable diaphragms or blade carriers. Nozzles or blades welded to the diaphragm are preferred (see 11.3.1).

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

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

7.4 External forces and moments

Turbines shall be designed to withstand external forces and moments at least equal to the values calculated in accordance with NEMA SM 23.

8 Rotating elements

8.1 General

8.1.1 Rotors shall be capable of safe operation at maximum overshoot speed of 121 % of maximum continuous speed at any specified operating temperature. Following such an excursion, the rotor shall be capable of operation without immediate maintenance intervention.

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

8.1.2 The purchaser's approval is required for built-up rotors (disks shrunk on the shaft) when blade tip velocities exceed 250 m/s (825 ft/s) at maximum continuous speed or when stage inlet steam temperatures exceed 440 °C (825 °F).

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

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

8.2 Shafts

8.2.1 Shafts shall be accurately finished throughout their entire length. The surface of the shaft at shrink fit areas and bearing areas shall be finished to a roughness not exceeding 0,8 µm (32 µin) *Ra*.

8.2.2 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized, sleeved or plated. The surface shall be finished to a roughness not exceeding 0,8 µm (32 µin) *Ra*. These areas shall be properly demagnetized to the levels specified in API Std 670 or otherwise treated so that the combined total electrical and mechanical runout does not exceed the following.

a) For areas to be observed by radial-vibration probes, 25 % of the allowed peak-to-peak vibration amplitude or 6,3 µm (0,25 mil), whichever is greater.

b) For areas to be observed by axial-position probes, 12,7 µm (0,5 mil).

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

8.2.4 Shafts shall be capable of transmitting torque at least equal to the torque determined by potential maximum power. The coupling shaft end design shall conform to the requirements of ISO 10441 or API Std 671.

8.2.5 To prevent the buildup of harmful potential voltage, magnetic flux density of any part of the rotating element shall not exceed 0,000 3 T (3 G).

8.3 Blading

8.3.1 For each blade row, the vendor shall verify by Campbell diagrams or their equivalent (corrected to actual operating temperatures and speeds), for both nozzle passing frequency and twice nozzle passing frequency, that excitation does not occur within the specified operating speed range for all multiples up to 15 times running speed. The following modes shall be verified:

— in-phase tangential;

— out-of-phase tangential;

— axial;

— torsional;

— any other high-response modes.

If this is not feasible, blade-stress levels developed in any specified driven-equipment operation shall be low enough to ensure trouble-free operation if resonant vibration occurs within the operating range. This shall be verified by Goodman diagrams or their equivalent. Copies of Campbell or Goodman diagrams or both shall be provided to the purchaser. Blades shall be designed to withstand operation at resonant frequencies during normal warm-up.

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

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

8.4 Speed-sensing element

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

9 Rotor dynamics

9.1 General

9.1.1 In the design of rotor-bearing systems, consideration shall be given to all potential sources of periodic forcing phenomena (excitations), which shall include, but are not limited to, the following:

a) unbalance in the rotor system;

b) oil-film instabilities (whirl);

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) hysteretic and friction whirl;

i) boundary-layer flow separation;

j) acoustic and aerodynamic cross-coupling forces;

k) asynchronous whirl;

l) electrical line frequency.

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

NOTE 2 When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor-bearing support system coincides with a natural frequency of that system, the system is in a state of resonance. A rotor-bearing-support-system in resonance can have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase-angle with respect to speed, are related to the amount of damping in the system.

NOTE 3 Publication 684 contains additional information on rotor dynamics not covered in this International Standard.

9.1.2 For the purposes of this International Standard, critical speeds and other resonant conditions of concern are those with an amplification factor greater than 2,5.

9.1.3 Resonances of structural support systems that are within the vendor’s scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the specified separation margins (see 9.2.9). The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor bearing support system [see 9.2.4 d)].

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

● **9.1.4** The vendor who is specified to have unit responsibility for the complete drive train shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. This shall be illustrated by the use of Campbell (forced frequency) diagrams for individual machines or, if specified, for the complete train, or for both. These diagrams shall be submitted to the purchaser for review and included in the instruction manual.

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

9.2 Lateral analysis

9.2.1 Critical speeds and their associated amplification factors shall be determined by means of a damped unbalanced rotor response analysis.

9.2.2 The location of all critical speeds below the trip speed shall be confirmed on the test stand during the mechanical running test by unbalancing the rotor if necessary. The accuracy of the numerical model shall be demonstrated (see 9.3).

9.2.3 Before carrying out the damped unbalanced response analysis, the vendor shall conduct an undamped analysis to identify the undamped critical speeds and determine the mode shapes located in the range from 0 % to 125 % of trip speed. Unless otherwise specified, the results of the undamped analysis shall be provided to the purchaser. The presentation of the results shall include:

a) mode shape plots (relative amplitude vs. axial position on rotor), and

b) critical speed-support stiffness map (frequency versus support stiffness) with the calculated support stiffness; horizontal, K_{xx}, and vertical, K_{yy}, (see Figure 1) superimposed on the map.

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

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

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

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

c) the pad pivot stiffness (for tilting pad bearings);

d) support[11] stiffness, mass, and damping characteristics, including effects of frequency dependent variation and for which

   1) the vendor shall state the support stiffness values used in the analysis and the basis for these values (e.g. modal tests of similar rotor support systems, or calculated support stiffness values),

   2) for machines whose bearing support stiffness values are less than or equal to 3,5 times the bearing oil-film stiffness values, support stiffness values derived from modal testing or calculated frequency dependent support stiffness and damping values (impedances) shall be used, and

   3) the value used for support stiffness should, in most cases, not exceed $0{,}875 \times 10^6$ N/mm (5×10^6 lbf/in);

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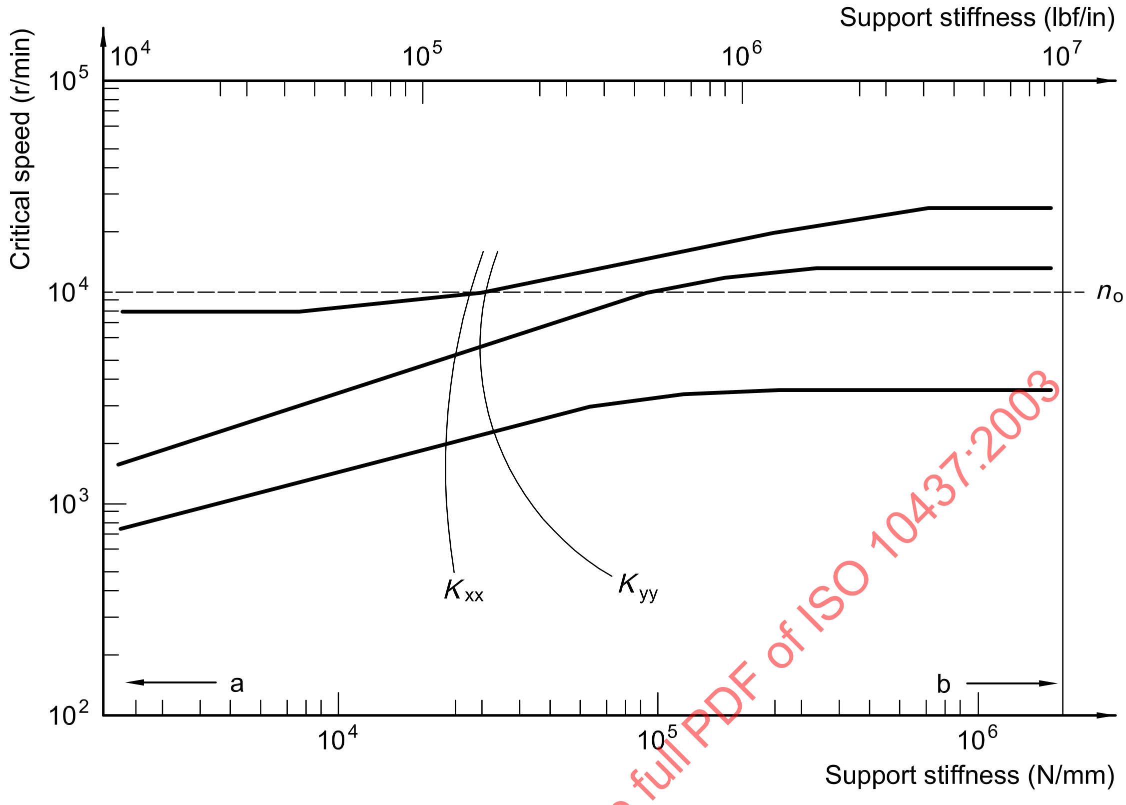
11) The term “support” includes the foundation or support structure, the base, the machine frame, and the bearing housing as appropriate.



Key

a low amplification factors

b high amplification factors

K_{xx} calculated support stiffness, horizontal

K_{yy} calculated support stiffness, vertical

n_o operating speed

Figure 1 — Undamped critical speed map

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

f) the influence, over the operating range, of values for hydrodynamic stiffness and damping generated by the casing end seals;

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

● **9.2.5** If specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (i.e. a train lateral analysis shall be performed). In particular, this analysis should be considered for machinery trains with rigid couplings.

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

In SI units:

$$U = \frac{6\,350 \times m}{n} \quad (1)$$

In US Customary units:

$$U = \frac{4 \times m}{n}$$

where

U is the input unbalance to be used in the rotor dynamic response analysis, expressed in gram-millimetres (ounce-inches);

m is the mass, as follows, expressed in kilograms (pounds):

— the rotor mass, for symmetric modes [see Figure 2 a) and c)];

— that portion of the rotor mass supported by the adjacent bearing, for asymmetric modes [see Figure 2 b) and d)];

— the overhung mass, i.e. the mass of the rotor outboard of the bearing, for overhung cantilevered modes [see Figure 2 e)];

— the overhung mass, i.e. the mass of the rotor outboard of the bearing, or the mass load on the adjacent bearing, whichever is greater, for overhung rigid modes [see Figure 2 f)];

n is the operating speed nearest the critical speed of concern, expressed in revolutions per minute.

9.2.7 As a minimum, the unbalanced response analysis shall produce the following:

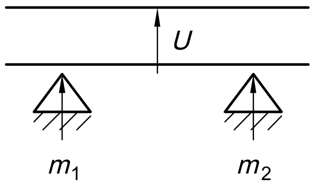
a) identification of the frequency of each critical speed in the range from 0 % to 125 % of the trip speed;

b) frequency, phase, and response amplitude data (Bode plots) at the vibration probe locations through the range of each critical speed resulting from the unbalance specified in 9.2.6;

c) the plot of the deflected rotor shape for each critical speed resulting from the unbalances specified in 9.2.6, showing the major-axis amplitude at each coupling plane of flexure, the centrelines of each bearing, the locations of each radial probe, and at each seal area throughout the machine as appropriate, while, in addition, the minimum design diametral running clearance of the seals shall be indicated;

d) additional Bode plots that compare absolute shaft motion with shaft motion relative to the bearing housing for machines where the support stiffness is less than 3,5 times the oil film thickness.

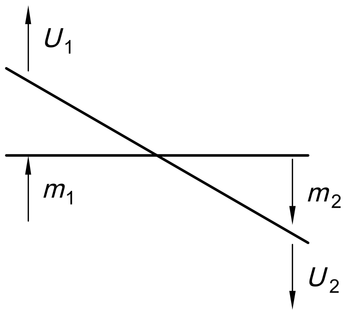
9.2.8 Additional analyses shall be made for use with the verification test specified in 9.3. The location and magnitude of the unbalance shall be determined by the vendor and approved by the purchaser. Any test stand parameters which influence the results of the analysis shall be included.



SI units: $U = 6\,350\,(m_1 + m_2)\,/\,n$

USC units: $U = 4\,(m_1 + m_2)\,/\,n$

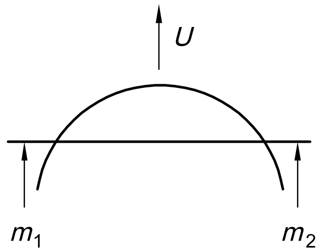
a) Translatory first rigid



SI units: $U_1 = 6\,350\,m_1\,/\,n$
$U_2 = 6\,350\,m_2\,/\,n$

USC units: $U_1 = 4\,m_1\,/\,n$
$U_2 = 4\,m_2\,/\,n$

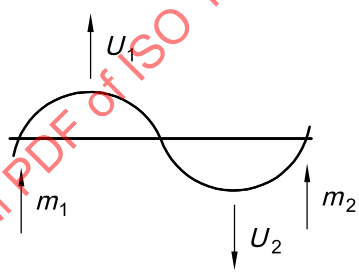
b) Conical, rocking second rigid



SI units: $U = 6\,350\,(m_1 + m_2)\,/\,n$

USC units: $U = 4\,(m_1 + m_2)\,/\,n$

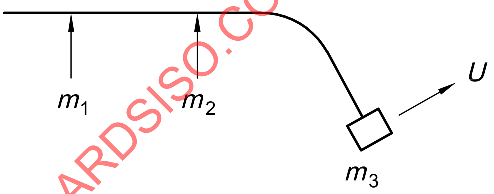
c) First bending



SI units: $U_1 = 6\,350\,m_1\,/\,n$
$U_2 = 6\,350\,m_2\,/\,n$

USC units: $U_1 = 4\,m_1\,/\,n$
$U_2 = 4\,m_2\,/\,n$

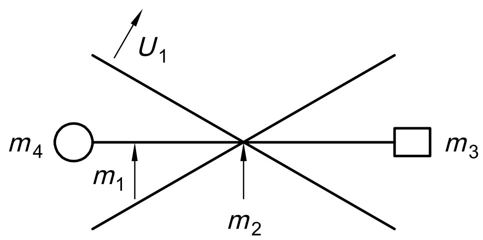
d) Second bending



SI units: $U = 6\,350\,m_3\,/\,n$

USC units: $U = 4\,m_3\,/\,n$

e) Overhung, cantilevered



SI units: $U_1 = 6\,350\,m\,/\,n$

USC units: $U_1 = 4\,m\,/\,n$

(where m is the larger of m_1 or m_4)

f) Overhung, rigid

Key

U unbalance mass, expressed in gram-millimetres (ounce-inches)

m see 9.2.6

n operating speed nearest speed of concern, expressed in revolutions per minute

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

Figure 2 — Typical mode shapes

9.2.9 The damped unbalanced response analysis shall indicate that the machine meets the following separation margins (see Figure 3).

a) If the amplification factor at a particular critical speed is less than 2,5, the response is considered critically damped and no separation margin is required.

b) If the amplification factor at a particular critical speed is 2,5 or greater, and that critical speed is below the minimum speed, the separation margin (M_s), as a percentage of the minimum speed, shall not be less than the value from Equation (2) or the value of 16, whichever is less.

$$M_s = 17 \times \left[1 - \frac{1}{F_a - 1{,}5}\right] \quad (2)$$

where

M_s is the separation margin;

F_a is the amplification factor.

c) If the amplification factor at a particular critical speed is 2,5 or greater, and that critical speed is above the maximum continuous speed, the separation margin, as a percentage of the maximum continuous speed, shall not be less than the value from Equation (3) or the value of 26, whichever is less.

$$M_s = 10 + 17 \times \left[1 - \frac{1}{F_a - 1{,}5}\right] \quad (3)$$

where

M_s is the separation margin;

F_a is the amplification factor.

9.2.10 The calculated unbalanced peak-to-peak amplitudes (see 9.2.7) shall be multiplied using the factor calculated using Equation (4).

$$F_c = \frac{A_1}{A_{4x}} \quad (4)$$

where

F_c is the correction factor;

A_1 is the amplitude limit, calculated using Equation (5), in µm (mil);

A_{4x} is the calculated peak-to-peak amplitude at the probe location in accordance with 9.2.7.b in µm (mil) peak to peak.

In SI units:

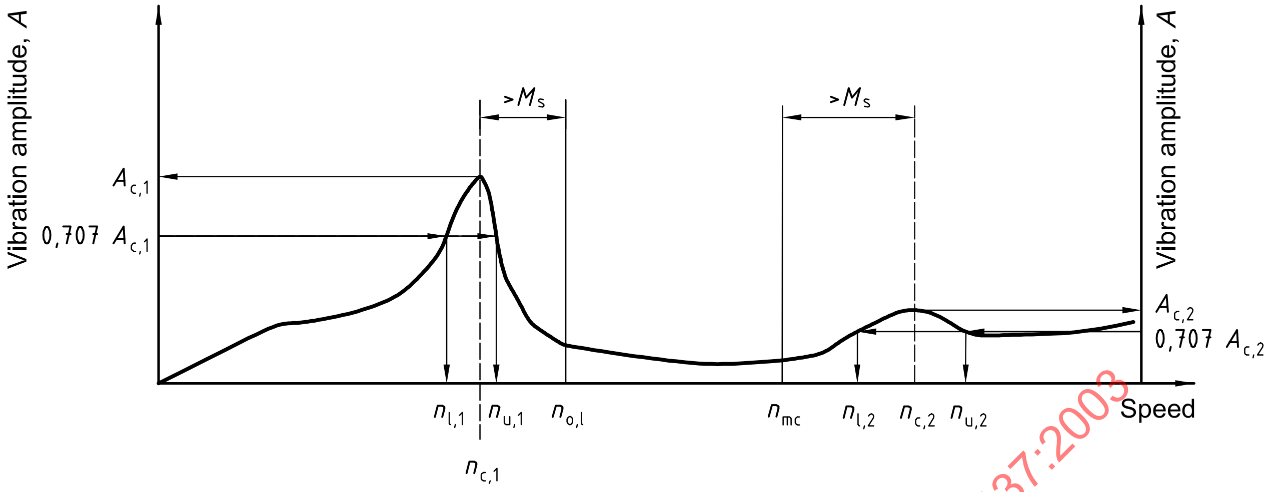
$$A_1 = 25{,}4 \times \sqrt{\frac{12\ 000}{n}} \quad (5)$$

In USC units:

$$A_1 = \sqrt{\frac{12\ 000}{n}}$$

where

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



Key

$n_{c,n}$	critical speed n
$n_{l,n}$	lower speed at 0,707 of amplitude at critical speed n
$n_{u,n}$	upper speed at 0,707 of amplitude at critical speed n
$n_{o,l}$	minimum operating speed
n_{mc}	maximum continuous speed, 105 % rated speed
$A_{c,n}$	amplitude at critical speed n
M_s	separation margin, function of F_a
F_a	amplification factor = $n_{c,n} / (n_{u,n} - n_{l,n})$

NOTE1 Operating speed range is from $n_{o,l}$ to n_{mc}

NOTE2 The shape of the curve is for illustration only and does not necessarily represent any actual rotor response plot; multiple critical speeds can be present below and above operating speed range.

Figure 3 — Rotor response plot

9.2.11 The calculated major-axis, peak-to-peak, unbalanced rotor response amplitudes, corrected in accordance with 9.2.10, at any speed from zero to trip speed, shall not exceed 75 % of the minimum design diametral running clearances throughout the machine.

NOTE Running clearances can be different from the assembled clearances with the machine shut down.

9.3 Unbalanced rotor response verification test

9.3.1 An unbalanced rotor response test shall be performed as part of the mechanical running test (see 16.3.3), and the results shall be used to verify the analytical model. The actual response of the rotor on the test stand to the same arrangement of unbalance as was used in the analysis specified in 9.2.8 shall be the criterion for determining the validity of the damped unbalanced response analysis. To accomplish this, the procedure given in a) to f), shall be performed.

a) During the mechanical running test (see 16.3.3), record the amplitudes and phase angle of the shaft vibration, from zero to trip speed. Preset the gain of any analog recording instruments used before the test so that the highest response peak is within 60 % to 100 % of the recorder's full scale on the test-unit coast-down (deceleration).

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

b) Establish the location of all critical speeds below the trip speed.

c) Add the unbalance agreed upon in accordance with 9.2.8 and which was used in the analysis performed in 9.2.8 to the rotor in the location used in the analysis. The unbalance shall not exceed eight times the value of U calculated in accordance with 9.2.6, Equation (1).

d) Bring the machine up to the operating speed nearest to the critical speed in question and record the indicated vibration amplitudes and phase using the same procedure used for a) above.

e) Vectorially subtract the corresponding indicated vibration data taken in accordance with a) from the results of this test.

f) Compare the results of the mechanical run, including the unbalance response verification test, with those from the analytical model specified in 9.2.8.

9.3.2 The vendor shall correct the model if it fails to meet either of the criteria contained in a) and b) below.

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

   It is possible, particularly on electric motors, that the vertical and horizontal stiffnesses are significantly different and the analysis predicts two differing critical speeds. Should the operating speed fall between these critical speeds, these two critical speeds should be treated separately, as if they resulted from separate modes.

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

9.3.3 If the support stiffness is less than two times the bearing oil film stiffness, the absolute vibration of the bearing housing shall be measured and vectorially added to the relative shaft vibration, in both the balanced [9.3.1 a)] and in the unbalanced [9.3.1 d)] condition, before proceeding with the step specified in 9.3.1 e). In such a case, the measured response shall be compared with the predicted absolute shaft movement.

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

9.3.5 The vibration amplitudes and phase from each pair of x-y vibration probes shall be vectorially summed at each vibration response peak after correcting the model, if required, to determine the maximum amplitude of vibration. The major axis amplitudes of each response peak shall not exceed the limits specified in 9.2.11.

9.4 Additional testing

9.4.1 Additional testing is required (see 9.4.2) if, from the corrected damped unbalance response analysis (9.2, 9.3.2), either of the following conditions exist:

a) any critical response fails to meet the separation margin requirements of 9.2.9;

b) the clearance requirements of 9.2.11 have not been met.

9.4.2 Unbalance masses shall be placed as described in 9.2.6; this may require disassembly of the machine. Unbalance magnitudes shall be achieved by adjusting the indicated unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by 9.2.10, Equation (5) at the maximum continuous speed; however, the unbalance used shall be no less than two or greater than eight times the unbalance limit specified in 9.2.6, Equation (1). The measurements from this test, taken in accordance with 9.3.1 a) and 9.3.1 b) shall meet the following criteria:

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

b) at no speed within the operating speed range, including the separation margins, shall the shaft deflections exceed 55 % of the minimum design running clearances or 150 % of the allowable vibration limit at the probes (see 9.2.10).

9.4.3 The internal deflection limits specified in 9.4.2 a) and 9.4.2 b) shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 9.2.11, based on a corrected model if required. Actual internal displacements for these tests shall be calculated by multiplying these ratios by the peak readings from the probes. Acceptance shall be based on these calculated displacements or inspection of the seals if the machine is opened. Damage to any portion of the machine as a result of this testing shall constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new-part tolerance do not constitute damage.

9.5 Torsional analysis

● **9.5.1** For units including gears or generators, or for units comprising three or more coupled machines, or if specified, the vendor having unit responsibility shall ensure that a torsional vibration analysis of the complete coupled train is performed and shall be responsible for directing any modifications necessary to meet the requirements of 9.5.2 to 9.5.6.

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

a) gear problems such as unbalance, pitchline runout, and cumulative pitch error;

b) cyclic process impulses;

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

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

e) control loop resonances from hydraulic, electronic governors, and variable frequency drives;

f) one or two times line frequency;

g) running speed or speeds;

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

9.5.3 The torsional natural frequencies of the complete train shall be at least 10 % above or 10 % below any possible excitation frequency within the specified operating speed range, from minimum governor speed to maximum continuous speed.

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

9.5.5 When torsional resonances are calculated to fall within the margin specified in 9.5.3 (and the purchaser and vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and vendor.

9.5.6 In addition to the torsional analysis required in 9.5.2 and 9.5.5, the vendor shall perform a transient torsional vibration analysis when synchronous motor or generator drives are part of the train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and vendor.

9.6 Vibration and balancing

● **9.6.1** Major parts of the rotating element, such as the shaft, balancing drum, and discs, shall be individually dynamically balanced before assembly to ISO 1940 Grade G1 or better. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half key in accordance with ISO 8821. Keyways 180° apart, but not in the same transverse plane, shall be filled. The initial balance correction to the bare shaft shall be recorded. The components to be mounted on the shaft (balance drum, disc, etc.) shall be balanced in accordance with the "half-key-convention" as described in ISO 8821.

9.6.2 The rotating element shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of no more than two major components, except on integral disc rotating elements. Balancing correction shall only be applied to the elements added. Minor correction of other components may be required during the final trim balancing of the completely assembled element. In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 9.6.1) shall continue to be used until they are replaced with the final key and mating element. On rotors with single keyways, the keyway shall be filled with a fully crowned half-key. The mass of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance work sheet (see Annex C). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units:

$$U_{\text{max}} = \frac{6\,350 \times m}{n} \qquad (6)$$

In USC units:

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

where

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

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

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

● **9.6.3** If specified, completely assembled rotating elements shall be subject to high-speed (at rated speed) balancing in lieu of a sequential low speed balancing (see 9.6.2). When the vendor's standard balancing method is by high-speed balancing in lieu of a sequential low-speed balancing and high-speed balancing is not specified, it may be used with the purchaser's approval. The high-speed balance shall be in accordance with 9.6.4.

9.6.4 When the complete rotating element has been specified to be high-speed balanced (9.6.3), 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. The final check balance shall be performed at maximum continuous speed. Before making any corrections (unless it is necessary to improve the initial balance in order to be able to run the rotor at high speed), the rotor shall be run in the balancing machine at trip speed for at least 5 min to allow seating of any shrunk-on components.

9.6.5 Unless otherwise specified, the vibration acceptance criteria for high-speed balancing, with maximum pedestal stiffness at all speeds, as measured on the bearing cap, shall be as follows:

a) for speeds above 3 000 r/min, it shall not exceed the "greater" of 7 400/n mm/s (291/n in/s) or 1 mm/s (0,039 in/s), where n is the speed, in revolutions per minute;

b) for speeds at or less than 3 000 r/min, it shall not exceed 2,5 mm/s (0,098 in/s).

- **9.6.6** A rotor that is to be high-speed balanced shall, if specified, first receive a sequential low-speed balance as specified in 9.6.2.

- **9.6.7** For a rotor that has been low-speed balanced (see 9.6.2), and if specified for rotors that are high–speed balanced (see 9.6.3), a low-speed residual unbalance check shall be performed in a low-speed balance machine in accordance with Annex C and recorded on the residual unbalance work sheet.

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

9.6.8 During the shop test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 25 µm (1,0 mil), whichever is less.

In SI units:

$$A = 25{,}4 \times \sqrt{\frac{12\,000}{n}} \qquad (7)$$

In USC units:

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

where

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

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

At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 % of the maximum value recorded at the maximum continuous speed.

IMPORTANT — Do not confuse these limits with the limits specified in 9.3 for shop verification of unbalanced response.

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

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

10 Bearings, bearing housings, and seals

10.1 Radial bearings

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

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

10.2 Thrust bearings and collars

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

10.2.2 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculation of the thrust load shall include, but shall not be limited to, the following factors:

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

b) step thrust from all diameter changes;

c) stage reaction and stage differential pressure;

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

e) external loads from the driven equipment in accordance with 10.2.3 and 10.2.4.

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

10.2.4 If two or more rotor thrust forces are to be carried by one thrust bearing, the resultant of the forces shall be used, provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

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

a) the shaft speed;

b) the temperature of the bearing babbitt;

c) the deflection of the bearing pad;

d) the minimum oil-film thickness;

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

f) the design configuration of the bearing;

g) the babbitt alloy;

h) the pad material;

i) the turbulence of the oil film.

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

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

10.2.7 Unless otherwise specified, integral thrust collars shall be furnished. They shall be provided with at least 3 mm (1/8 in) of additional stock on total thickness to enable refinishing if the collar is damaged. When replaceable collars are furnished, they shall be shrunk on, and positively locked to, the shaft to prevent fretting.

10.2.8 Both faces of thrust collars shall be finished to a surface roughness not exceeding 0,8 µm (32 µin) *Ra*. The axial total indicated runout of either face shall not exceed 13 µm (0,000 5 in).

10.3 Bearing housing

10.3.1 Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 30 °C (50 °F) under the most adverse specified operating conditions. The bearing outlet oil temperature shall not exceed 80 °C (180 °F). When the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow, and allowable temperature rise. Oil outlets from flooded thrust bearings shall be tangential and in the upper half of the control ring or, if control rings are not used, in the thrust-bearing cartridge.

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

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

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

10.3.5 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. The probe installation shall be as specified in API Std 670.

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

10.4 Grounding

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

10.5 Shaft seals

10.5.1 Unless otherwise specified, casing end seals shall be replaceable labyrinth seals.

10.5.2 Interstage sealing shall be by replaceable labyrinths.

10.5.3 Labyrinth casing end seals operating at less than atmospheric pressure shall be designed for admission of dry steam to seal against air ingress. 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. The admission and the pressure of the sealing steam shall be automatically controlled. The normal operating sealing steam supply should preferably come from a positive pressure section of the turbine.

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

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

11 Materials

11.1 General

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

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

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

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

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

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

● **11.1.6** The purchaser shall specify any corrosive agents exceeding IEC 60045-1 or NEMA SM 23 steam quality requirements present in the steam and in the environment, including constituents that may cause stress corrosion cracking.

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

11.1.7 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.

11.1.8 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound of the appropriate temperature specification and compatible with steam.

NOTE Torque loading values differ considerably with and without an anti-seizure compound.

● **11.1.9** If the purchaser has specified the presence of hydrogen sulfide in any fluid, materials exposed to that fluid shall be selected in accordance with the requirements of NACE MR0175. Ferrous materials not covered by NACE MR0175 shall not have a yield strength exceeding 620 N/mm^2 (90 000 psi) or a hardness exceeding Rockwell C 22. Components that are fabricated by welding shall be postweld heat treated, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements.

In many applications, small amounts of wet H_2S are sufficient to require materials resistant to sulfide stress corrosion cracking. When there are trace quantities of wet H_2S known to be present or if there is any uncertainty about the amount of wet H_2S that may be present, the purchaser should automatically note on the data sheets that materials resistant to sulfide stress corrosion cracking are required.

NOTE It is the responsibility of the purchaser to determine the amount of wet H_2S that may be present, considering normal operation, startup, shutdown, idle standby, upsets or unusual operating conditions such as catalyst regeneration.

11.1.10 Unless otherwise specified, the vendor shall list in the proposal all steam path components (valves, seats, blades, shrouds, closing pieces, pins, damping wires, wheels, bolting, and so forth) with a hardness of more than Rockwell C 22. The vendor shall also indicate the hardness range of each component.

11.1.11 Pressure-containing parts subject to steam conditions exceeding gauge pressures of 520 kPa (5,2 bar) (75 psi) or temperatures of 230 °C (450 °F) shall be steel. In the case of the exhaust casing of non-condensing turbines, this shall be based on the maximum specified exhaust pressure and the maximum no-load exhaust temperature. Alloy steels shall be used for maximum steam temperatures exceeding 410 °C (775 °F).

11.1.12 The material limits for pressure bolting based upon the actual bolting temperature shall be as specified in ISO 15649. Nuts shall conform to ASTM A 194, Grade 2H (or ASTM A 307, Grade B, case-hardened, where space is limited) or better material.

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

11.1.13 Material for turbine wheels and shafts shall be forged steel. Unless otherwise approved, 11 % to 13 % chromium steel, titanium, or nickel-copper alloy (similar to ASTM B 127) shall be used for nozzles, closing pieces, rotating and stationary blading, shrouding and steam strainers.

11.1.14 Bearing surfaces (journals and thrust faces) shall be of a material containing less than 2,5 % Cr, to prevent the risk of wire wool type bearing failures.

11.1.15 Low-carbon steels can be notch-sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice shall be used. Steel made to a coarse grain size practice (such as ASTM A 515) shall not be used.

- The purchaser shall specify the minimum design metal temperature used to establish impact test and other material requirements.

11.2 Castings

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

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

11.2.3 If repairs to castings are necessary, pressure-containing ferrous castings shall not be repaired except as follows.

a) Weldable grades of castings shall be repaired by welding, using a qualified welding procedure (including pre- or post-weld heat treatment or both, when necessary) as specified in Table 3. After major weld repairs, and before hydrostatic testing, the complete casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining.

b) Cast iron may be repaired by plugging within the limits specified in ASTM A 278, ASTM A 395 or ASTM A 536. 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. All major repairs, as defined by the material specifications, shall be recorded (on a drawing, if appropriate) and reported [see 16.2.1.1 g)] as part of the vendor's documentation (11.3.2).

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

11.2.5 Nodular iron castings shall be produced in accordance with an internationally recognized standard such as ASTM A 395. The production of the castings shall also conform to the conditions specified in a) to e), as follows.

a) The keel or Y-block cast at the end of the pour shall be at least as thick as the thickest section of the main casting. This test block shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules under microscopic examination shall be in accordance with ASTM A 247.

b) If critical sections of a casting have different thicknesses, average size keel or Y blocks may be selected in accordance with ASTM A 395. Minimum quality levels should be agreed upon between the purchaser and the vendor. Critical sections are typically heavy sections, section changes and high-stress points. Normally, bosses and similar sections are not considered critical sections of a casting.

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

d) Integrally cast test bosses, preferably at least 25 mm (1 in) in height and diameter, shall be provided at critical areas of the casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, flanges and other high-stress points as agreed upon by the purchaser and the vendor. Classification of graphite nodules shall be in accordance with ASTM A 247.

e) An “as-cast” sample from each ladle shall be chemically analysed.

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

11.3 Welding

11.3.1 Welding and weld repairs shall be performed by operators, and in accordance with procedures, qualified to the requirements of Table 3. Alternative standards may be proposed by the vendor for the purchasers approval. The datasheets in Annex A may be used for this purpose.

Table 3 — Welding requirements

Requirement	Applicable code or standard
Welder/operator qualification	ASME IX or EN 287
Welding procedure qualification	Applicable material specification or, where weld procedures are not covered by the material specification, ASME IX or EN 288
Non-pressure-retaining structural welding such as baseplates or supports	AWS D1.1
Magnetic particle or liquid penetrant examination of the plate edges	ASME VIII, Division 1, UG-93(d)(3)
Post-weld heat-treatment	Applicable material specification or ASME VIII, Division 1, UW 40
Post-weld heat-treatment of casing fabrication welds	Applicable material specification or ASME VIII, Division I

11.3.2 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. As a minimum, the inspection shall be by the magnetic particle method for magnetic material, and by the liquid penetrant method for non-magnetic materials, in accordance with 16.2.2. Unless otherwise specified, procedures for major repairs shall be subject to review by the purchaser before any repair is made [see 11.2.3 c)]

11.3.3 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in a) to d), as follows.

a) Plate edges shall be inspected by magnetic particle or liquid penetrant examination as specified in 11.3.1.

b) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after post-weld heat treatment.

● If specified, the quality control of welds that are inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

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

d) Fabricated casings (regardless of thickness) shall be post-weld heat treated.

11.3.4 Connections welded to pressure casings shall be installed as specified in a) to d), as follows.

a) In addition to the requirements of 11.3.1, the purchaser may specify that 100 % radiography, magnetic particle inspection or liquid penetrant inspection of welds is required.

b) Auxiliary piping welded to chromium-molybdenum alloy steel or 12 % chromium steel components shall be of the same material, except that chromium-molybdenum alloy steel pipe may be substituted for 12 % chromium steel pipe.

c) If heat treatment is required, piping welds shall be made before the component is heat treated.

d) All welds shall be heat treated as specified in Table 3.

12 Controls and instrumentation

12.1 General

The wiring and installation of instrumentation control and electrical systems shall conform to the purchaser's specifications and, unless otherwise specified, shall conform to the requirements of ISO 10438 and API Std 670.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

12.2 Turbine governing system

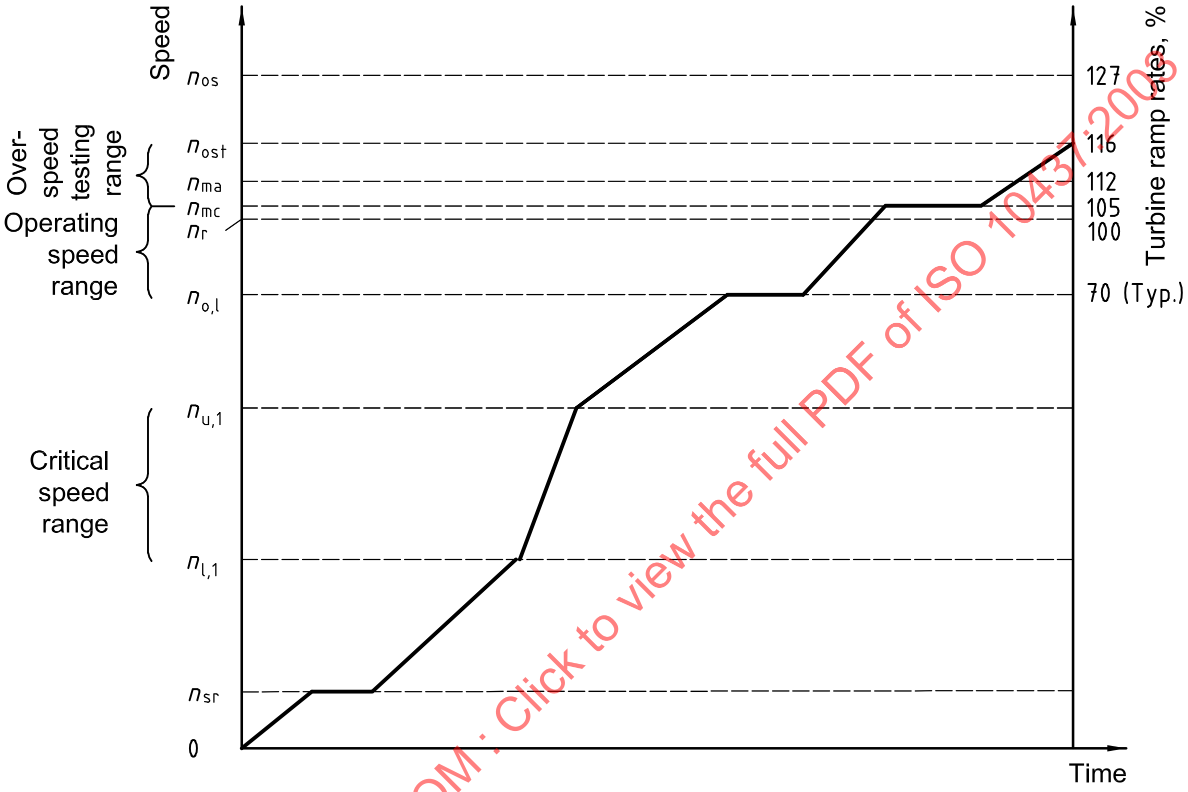
12.2.1 The governing system is the primary system necessary to match the turbine output to the application. The governing system includes the speed governor, control mechanism and governor-controlled valve(s). The turbine vendor shall have unit responsibility for the entire governing system. For generator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

NOTE The relationship between the various turbine speeds is illustrated in Figure 4.

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

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

12.2.3 A dedicated digital microprocessor-based governor unit shall be furnished. This unit shall be separate and independent of any overall system such as a distributed control system (DCS) and shall be provided with electrical power by a purchaser-supplied uninterruptible power source.



Key

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

Figure 4 — Turbine ramp speeds

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

a) The speed regulation at rated speed and rated steam inlet and exhaust conditions shall not exceed 0,5 %. Speed regulation is defined as:

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

where

n_{P0} is the speed at zero power;

n_{PR} is the speed at rated power.

b) The steady state speed variation at rated speed, rated power and rated steam inlet and exhaust conditions, shall not exceed 0,25 %. Speed variation is defined as:

$$\frac{n_{i,max} - n_{i,min}}{2 \times n_r} \times 100\ \%$$

where

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

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

n_r is the rated speed;

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

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

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

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

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

b) speed setpoint adjustment;

c) remote or process controlled speed setpoint 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) manually activated override for testing the overspeed shutdown system;

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

12.2.8 The speed of the turbine shall vary linearly with the setpoint signal. An increase in setpoint signal shall increase turbine speed.

12.2.9 The governing system shall provide for both slow roll (typically 400 r/min to 500 r/min) and startup using the governor-controlled valves.

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

12.2.11 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 initiate a signal to close non-return valve(s).

12.2.12 The shutdown system shall prevent opening of the trip valve(s) if the governor-controlled valve(s) are not fully closed.

● **12.2.13** Additional modes of control, such as single controlled extraction/induction, shall be as specified by the purchaser.

12.2.14 The level of redundancy and fault tolerance shall be as required to meet the five-year uninterrupted service expectation (see 6.1.1).

12.3 Overspeed shutdown system

12.3.1 General

12.3.1.1 A dedicated overspeed shutdown system capable of independently shutting down the turbine shall be provided. This system shall not be dependent on the governing system or any other system. The system shall prevent the turbine rotor speed from exceeding 127 % of the rated speed on an instantaneous, complete loss of coupled inertia and load while operating at the rated conditions. In the event of loss of load without loss of coupled inertia, and unless otherwise specified by the driven equipment vendor, the system shall prevent the speed from exceeding 120 % of rated speed. The turbine vendor shall have unit responsibility for the overspeed shutdown system.

12.3.1.2 The overspeed shutdown system shall include, but not be limited to, the following:

a) electronic overspeed detection system (speed sensors and logic devices);

b) electro-hydraulic solenoid valves;

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

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

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

12.3.1.4 On controlled extraction turbines, the vendor shall supply a non-return valve, equipped with a spring-loaded hydraulic or pneumatic actuated cylinder to assist in closing the valve, on each extraction line. The hydraulic or pneumatic cylinder on these valves shall be actuated by the shutdown system. The manufacturer, model, quantity and location of the device(s) shall be agreed by the purchaser and the turbine vendor.

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

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

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

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

12.3.1.5 On turbines with uncontrolled extractions, two non-return valves in series shall be provided on each extraction.

12.3.2 Electronic overspeed detection system

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

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

12.3.3 Electro-hydraulic solenoid valves

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

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

12.3.3.3 Unless otherwise specified, solenoid valves shall be de-energized to shutdown. The solenoid valves shall be in series, be close to the trip valve(s) or trip and throttle valve(s), and have no other device between them and the trip valve(s) or trip and throttle valve(s) except test isolation valves.

Test isolation valves, where used, should be locked in the open position for normal operation.

12.3.3.4 If energize to shutdown is specified, the solenoid valves shall be in parallel and the solenoids and relays shall have a detection system to alarm on failure of the coil.

12.3.3.5 The solenoid valves and any required interposing relays shall be capable of on-line testing without defeating trip protection.

Solenoids can draw significantly high currents. Interposing relays may be used when the current requirements of the solenoids exceed the current rating of the relay in the overspeed shutdown system.

12.3.3.6 De-energizing of solenoid valves shall be initiated by the electronic overspeed detection system or the operation of other shutdown systems (see 12.4).

12.3.4 Trip valves/combined trip and throttle valves

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

h) corrosion-resistant steam strainer;

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

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

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

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

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

12.3.4.7 The time from the overspeed condition to full closure of the trip valve shall not exceed the time calculated by the turbine vendor to meet the requirements of 12.3.1.1. The calculation methodology shall be in accordance with ASME PTC 20.2.

12.4 Other alarms and shutdowns

12.4.1 An alarm/shutdown system shall be provided in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

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

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

a) Alarms:

- overspeed shutdown system fault;
- failure of any one governor speed sensor;
- low lube oil pressure;
- high exhaust pressure;
- high radial vibration;
- axial displacement;
- high bearing temperature;
- low control oil pressure;
- low/high extraction pressure;
- low steam inlet temperature;
- high exhaust temperature (condensing turbines).

b) Shutdowns:

- overspeed (see 12.3);
- failure of all governor speed sensors;
- very low lube oil pressure;
- very high radial vibration;
- high axial displacement;
- very high bearing temperature.

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

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

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

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

12.4.7 Unless otherwise specified, the alarm/shutdown system shall comply with the requirements of ISO 10438 and a) to c) as follows.

NOTE 1 For the purpose of this provision, API 614 is equivalent to ISO 10438.

NOTE 2 It is accepted that with some systems, particularly those based on conventional, direct-acting instruments, complete compliance with the requirements of a) to c) as follows may not be possible.

NOTE 3 Examples of alarm/shutdown system arrangements generally considered acceptable are given in Annex D.

a) When any component of the alarm/shutdown system malfunctions, an alarm shall be initiated which shall be distinguishable from alarms associated with an equipment parameter reaching the alarm or shutdown point.

   NOTE Redundant sensors could be required to accomplish this.

b) When any malfunction of a component of the shutdown system results in the system being unable to recognize a shutdown condition, the turbine shall be caused to shutdown (a fail safe system).

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

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

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

12.4.9 Where alarm or shutdown functions or both are initiated by locally mounted switches, such switches shall comply with a) to c) as follows.

● a) The purchaser shall specify whether switches shall be connected to open (de-energize) or close (energize) to initiate alarms.

● b) Temperatures shall be measured by thermocouples or resistance temperature detectors, as specified, which shall be connected to local panel-mounted instruments. Multipoint instruments may be used, except that alarms and shutdowns shall be connected to separate instruments and separate alarm or shutdown contacts (switches) shall be provided for each temperature monitored and each alarm and shutdown level shall be separately adjustable.

● c) Vibration, axial position and/or bearing temperature switches shall be provided by instruments complying with the requirements of API Std 670.

12.5 Instrument and control panels

12.5.1 Unless otherwise specified, instrument and control panels shall conform to ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

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

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

12.6 Indicating instrumentation

12.6.1 Tachometers

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

12.6.1.2 The speed signals may be obtained from the speed sensors provided for turbine governing or from independent sensors (see 12.2.5 and 12.2.6).

12.6.2 Temperature gauges

12.6.2.1 Dial temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 115 mm (4,5 in) in diameter and bimetallic or gas-filled and, unless otherwise agreed, shall have black printing on a white background.

12.6.2.2 Liquid-filled temperature gauges shall not be used.

12.6.3 Thermowells

Thermowells shall be in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

12.6.4 Thermocouples and resistance temperature detectors

Thermocouples and resistance temperature detectors shall be in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

12.6.5 Pressure gauges

Pressure gauges shall be in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

13 Electrical systems

Electrical systems shall conform to the purchaser's specifications and, unless otherwise specified, shall conform to the requirements of ISO 10438 and API Std 670.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

14 Piping and appurtenances

14.1 General

14.1.1 Piping design, fabrication, examination and inspection shall be in accordance with the codes and standards specified and shall conform to the requirements of ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

14.1.2 Threaded connections shall not be seal-welded.

If welding in a particular location is acceptable, the connection shall be welded and not threaded.

14.1.3 Unless otherwise specified, pipe-flange gaskets shall be spiral-wound metal or metal-jacketed with non-hazardous filler for steam temperatures above 260 °C (500 °F) or steam gauge pressures above 2 800 kPa (28 bar) (400 psi). The manufacturer's standard gasket may be used below these limits.

14.2 Oil piping

Oil piping design, fabrication, examination and inspection shall be in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

14.3 Instrument piping

Instrument piping design, fabrication, examination and inspection shall be in accordance with ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

15 Accessories

15.1 Couplings and guards

15.1.1 When the turbine vendor supplies tandem drivers, the vendor shall furnish flexible coupling(s) and guard(s) between the units. Unless otherwise specified, all other couplings and guards shall be supplied by the vendor of the driven equipment.

● **15.1.2** Couplings shall conform to ISO 10441 or API Std 671. The make, type, and mounting arrangement of the couplings shall be as specified by the purchaser and agreed by the vendors of the driver and driven equipment.

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

15.1.4 Where a coupling is to be mounted on the turbine shaft with a tapered fit, the correct machining of the taper shall be confirmed by the use of a matched plug and ring gauge, unless an alternative method of confirming the correct fit has been agreed.

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

15.1.6 Coupling mass simulator(s) (or by agreement, moment simulators), in accordance with ISO 10441 or API Std 671, shall be provided to enable the turbine to be properly tested before shipment.

15.1.7 Idling adapter(s) (solo plates), and bolting in accordance with ISO 10441 or API Std 671, shall be furnished, if required, to enable the turbine to be run uncoupled from the driven equipment without requiring removal of the half coupling. The idling adapter(s) shall be supplied to the purchaser as part of the special tools.

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

15.1.9 Coupling guards shall be designed and manufactured in accordance with Annex E.

15.2 Gear units

Gear units shall conform to ISO 13691 or API Std 613.

15.3 Mounting plates

15.3.1 General

● **15.3.1.1** 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 F.

15.3.1.2 Mounting plates shall be equipped with vertical levelling screws. Baseplate levelling jackscrews shall be located at each anchor bolt location.

15.3.1.3 If an item of equipment supported has a mass in excess of 225 kg (500 lb), the mounting plates shall be furnished with horizontal jackscrews (axial and lateral) the same size as or larger than the equipment vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates in such a manner that they do not interfere with the installation or removal of the equipment jackscrews or shims. Precautions shall be taken to prevent vertical jackscrews in the equipment feet from marring the shimming surfaces. Alternative methods of lifting equipment for the removal or insertion of shims or for moving equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed. Such arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews. Jackscrews shall be plated for rust resistance.

15.3.1.4 Machinery supports shall be designed to limit the relative displacement of the shaft ends caused by the worst combination of pressure, torque, and allowable piping stress to 50 µm (0,002 in). See 7.4 for allowable piping forces.

15.3.1.5 When pedestals or similar structures are provided for centreline support, they shall be designed and fabricated to permit the machine to be moved using horizontal jackscrews.

15.3.1.6 The upper and lower surfaces of mounting plates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 6 µm (250 µin) arithmetic average roughness (Ra).

15.3.1.7 The vendor shall blast clean all grout contact surfaces on the mounting plates in accordance with ISO 8501 Grade Sa2 or SSPC-SP6/NACE No. 3, and shall coat those surfaces compatible with epoxy grout. Grouts other than epoxy could require alternative surface preparation. Full bond strength of epoxy is not generally necessary.

15.3.1.8 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 levelling screws;

c) mounting plates which are in contact with the grout shall have 50 mm (2 in) minimum radiused outside corners (in the plan view);

d) all machinery mounting surfaces shall be treated with a rust preventative immediately after machining;

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

● **15.3.1.9** The purchaser shall specify who is to supply the anchor bolts.

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

15.3.1.11 Unless otherwise specified, horizontal jackscrews and levelling screws shall be provided by the supplier of the mounting plate(s).

15.3.1.12 The supplier of the mounting plates shall furnish austenitic stainless steel shim packs not less than 3 mm (1/8 in) total thickness and not more than 13 mm (1/2 in) thick between the equipment feet and the mounting plates. All shim packs shall straddle hold-down bolts and vertical jackscrews and shall be at least 6 mm (1/4 in) larger on all sides than the equipment feet.

● **15.3.1.13** If levelling plates are specified, they shall be steel plates at least 19 mm (3/4 in) thick. They shall be circular in shape in the plan view.

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

15.3.2 Baseplates

● **15.3.2.1** If a baseplate is specified, the purchaser shall indicate the major equipment to be mounted on it. A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces which shall be bolted together to ensure accurate field reassembly.

NOTE A baseplate with 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.

● **15.3.2.2** If specified, the baseplate shall be suitable for column mounting that is of sufficient rigidity to be supported at specified points without continuous grouting under structural members. The design of column mounted baseplates shall be agreed upon by the purchaser and the vendor.

● **15.3.2.3** If specified, the baseplate shall be designed to facilitate the use of optical, laser-based or other instruments for accurate levelling in the field. The details of such features shall be agreed upon by the purchaser and the vendor. Where levelling pads or targets or both these are supplied, they shall be accessible with the baseplate or baseplates on the foundation and the equipment mounted. Removable protective covers shall be provided. For column-mounted baseplates, pads or targets shall be located close to support points. For non-column-mounted baseplates, a pad or target shall be located at each corner. When required, additional pads or targets shall be located at intermediate points.

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

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

● **15.3.2.5** The bottom of the baseplate between structural members shall be open. When the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 0,01 m^2 (20 in^2) and no dimension less than 75 mm (3 in) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with equipment installed. The holes shall have 13 mm (1/2 in) raised-lip edges and, if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 1 mm (16 gauge) shall be provided. Vent holes at least 13 mm (1/2 in) in size shall be provided at the highest point in each bulkhead section of the baseplate.

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

● **15.3.2.7** If specified, subplates shall be provided by the supplier of the baseplate.

15.3.2.8 Unless otherwise specified, non-skid decking covering all walk and work areas shall be provided on top of the baseplate.

15.3.2.9 After baseplate fabrication, the equipment mounting surfaces shall meet the following criteria:

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

b) mounting surfaces in one plane shall be machined such that no point on any surface deviates from the common plane by more than 50 µm (0,002 in);

c) different mounting planes shall be parallel to each other within 1 in 1 000, in any direction.

15.3.3 Soleplates and subplates

If soleplates are furnished, they shall meet the requirements of a) to c), as follows, in addition to those of 15.3.1.

NOTE See Annex F for a typical sketch.

a) Adequate working clearance shall be provided at the bolting locations on soleplates to allow the use of socket or box wrenches and to allow the equipment to be moved using the horizontal and vertical jackscrews.

b) Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, without distortion of the soleplate, but in no case shall the plates be less than 40 mm (1 1/2 in) thick.

● c) If specified, subplates shall be supplied and shall be steel, a minimum of 25 mm (1 in) thick, and have a mating surface finish of 3 µm to 6 µm (125 µin to 250 µin) *Ra* or better. Corners shall be rounded to a minimum 50 mm (2 in) radius in the plan view.

15.4 Relief valves

15.4.1 The vendor shall furnish the relief valves that are to be installed on equipment or in piping within their scope of supply. Other relief valves shall be furnished by the purchaser. The vendor shall advise the purchaser of the flow rate, set pressure, and temperature for purchaser's use in relief valve sizing and selection. The vendor's quotation shall list all relief valves and shall clearly indicate those to be furnished by the vendor.

15.4.2 The sizing, selection and installation of relief valves shall meet the requirements of API RP 520, Parts I and II. Relief valves shall be in accordance with API Std 526. The vendor shall determine the size and set pressure of all relief valves within their scope of supply and recommend the size and setting of relief valves supplied by others required to protect the equipment. Relief valve sizes and set pressures shall take account of all possible modes of equipment failure.

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

● **15.4.4** If specified, thermal relief valves shall be provided for components that contain liquid and could be blocked in by isolation valves.

15.5 Lubrication and control-oil system

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

● **15.5.2** If specified, the turbine vendor shall furnish a pressurized oil system to supply oil at a suitable pressure or pressures, as applicable, to the following:

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

b) any continuously lubricated couplings;

c) the control-oil system;

d) the shutdown system.

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

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

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.

15.5.4 Pressurized oil systems shall conform to ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

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

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

15.5.6 Any points that require grease lubrication during operation and which cannot be easily and safely accessed during operation shall be provided with austenitic stainless steel extension lines shielded from heat if necessary.

15.6 Gland vacuum systems

15.6.1 Unless otherwise specified, a gland vacuum system shall be furnished by the vendor (see typical system in Annex G). It shall include a gland condenser and steam ejector sized for three times the expected flow with "as new" shaft seal clearances. The condenser shall have a steel shell, brass or cupro-nickel tubes with a nominal wall thickness of not less than 1,25 mm (0,050 in) and a diameter of at least 15 mm (5/8 in), and fixed tube sheets with water on the tube side. U-tubes shall not be used. The water side (tube side) shall conform to the requirements of 6.1.13. The shell side shall be designed for both full vacuum and gauge pressure of 500 kPa (5 bar) (75 psi). The steam ejector shall have a steel body and a replaceable stainless steel steam nozzle.

● **15.6.2** If specified, a vacuum pump shall be provided in place of a steam ejector.

15.7 Insulation and jacketing

● **15.7.1** If specified or required by the vendor, turbines shall be insulated and jacketed. The insulation and jacketing shall extend over all parts of the turbine casing that can reach a normal operating temperature of 74 °C (165 °F) or higher.

If insulation is not supplied, the vendor should advise the purchaser of the expected surface temperature of the casing and any special requirements. This applies to the turbine casing and does not include any auxiliary steam piping or bolted-on trip or trip and throttle valves.

NOTE A jacket is a metal lagging or cover over the unit. A blanket is a removable, reusable, fit insulation skin which is wired to the turbine casing.

15.7.2 The insulation shall maintain an external surface temperature of not more than 74 °C (165 °F) under normal operating conditions. Jackets and insulation shall be designed to minimize possible damage during removal and replacement.

15.8 Turning gear

● **15.8.1** A turning gear shall be provided if specified by the purchaser or required by the vendor.

NOTE The need for a turning gear is typically determined by the bearing span and the rotor's vulnerability to temporary bow during shutdown.

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

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

15.8.4 Engagement of the turning gear on shutdown before the rotor has come to a stop shall be positively prevented if this could damage the turning device or the steam turbine.

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

15.8.6 The turning-gear rotational speed and torque shall be agreed upon by the purchaser and the vendor. Consideration shall be given to duration of use, minimum speed required for the turbine and driven equipment, and the type of lube-oil supply.

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

15.9 Special tools

15.9.1 When special tools and fixtures are required to disassemble, assemble or maintain the turbine unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multi-unit installations, the requirements for quantities of special tools and fixtures shall be agreed upon by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

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

● **15.9.3** When spreader beams or other special lifting devices are required for installation or maintenance, they shall be provided by the vendor, unless otherwise specified. The purchaser shall specify whether these devices shall be provided on loan or for permanent retention by the owner.

16 Inspection, testing and preparation for shipment

16.1 General

16.1.1 After advance notification to the vendor, the purchaser's representative shall have entry to all vendor and subvendor facilities where manufacturing, testing or inspection of the equipment is in progress.

16.1.2 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

16.1.3 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed. For mechanical running or performance tests, this requires written notification of a successful preliminary test.

The purchaser should expect to be in the factory longer for an observed test than for a witnessed test.

● **16.1.4** The purchaser shall specify the extent of his participation in the inspection and testing and the amount of advance notification he requires.

16.1.5 If shop inspection and testing have been specified by the purchaser, the purchaser and the vendor shall meet to coordinate manufacturing hold points and inspectors' visits.

16.1.6 Equipment, materials and utilities for the specified inspection and tests shall be provided by the vendor.

● **16.1.7** If specified, the purchaser's representative, the vendor's representative or both shall indicate compliance with this International Standard by initialling, dating and submitting a completed checklist to the purchaser before shipment. For a typical inspector's checklist, see Annex I.

16.1.8 The purchaser's representative shall have access to the vendor's quality-control program for review.

16.2 Inspection

16.2.1 General

16.2.1.1 The vendor shall keep the following data available for at least 20 years:

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

b) specifications for all purchased items;

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

d) test data to verify that the requirements of the specification have been met;

e) results of quality-control tests and inspections;

f) final-assembly maintenance and running clearances;

g) details of all major repairs [see 11.2.3 c) and 11.3.2].

h) other data specified by the purchaser or required by applicable codes and regulations (see 17.3).

NOTE 1 Test data applies to such tests as hydro and running, as well as NDE results.

NOTE 2 A summary of typical component inspections is given in Annex H.

16.2.1.2 Pressure-containing parts shall not be painted until the specified pressure testing of the parts is completed.

● **16.2.1.3** In addition to the requirements of 11.3.1, the purchaser may specify the following:

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

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

16.2.2 Materials inspection

● NDE shall be performed as required by the material specification. If additional radiographic, ultrasonic, magnetic particle or liquid penetrant examinations of the welds or materials are specified by the purchaser, the methods and acceptance criteria shall be in accordance with the standards shown in Table 4 or alternative standards specified by the purchaser or proposed by the vendor and agreed by the purchaser.

Radiography should normally be considered for steam gauge pressures exceeding 8 600 kPa (86 bar) (1 250 psi) or steam temperatures exceeding 510 °C (950 °F).

Table 4 — Materials inspection standards

Type of inspection	Methods	Acceptance criteria	
		For fabrications	For castings
Radiography	Section V, Articles 2 and 22 of the ASME Code	Section VIII , Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the ASME Code	Section VIII, Division 1, Appendix 7 of the ASME Code
Ultrasonic inspection	Section V, Articles 5 and 23 of the ASME Code	Section VIII, Division 1, Appendix 12, of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code
Magnetic particle inspection	Section V, Articles 7 and 25 of the ASME Code	Section VIII, Division 1, Appendix 6 of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code
Liquid penetrant inspection	Section V, Articles 6 and 24 of the ASME Code	Section VIII, Division 1, Appendix 8 of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code

Forgings used for turbine shafts, disks, and rotors with integrally forged disks shall be inspected by ultrasonic methods in accordance with ASTM A 418.

Unless otherwise specified, a heat stability check shall be performed on the turbine shaft or rotor forging in accordance with ASTM A 472.

16.2.3 Mechanical inspection

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

16.2.3.2 All oil system components furnished shall meet the cleanliness requirements of ISO 10438.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

● **16.2.3.3** If specified, the purchaser may inspect for cleanliness the equipment and all piping and appurtenances before installation of nozzle blocks and steam-chest covers, final assembly of piping, or closure of openings.

● **16.2.3.4** If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation, and witnessing of the testing shall be agreed by the purchaser and the vendor.

16.3 Testing

16.3.1 General

16.3.1.1 Equipment shall be tested in accordance with 16.3.2 and 16.3.3. Other tests that may be specified by the purchaser are described in 16.3.4.

16.3.1.2 At least six weeks before the first scheduled mechanical running test, the vendor shall submit to the purchaser for his review and comment, detailed procedures for all running tests, and all specified optional tests (16.3.4), including acceptance criteria for all monitored parameters.

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

16.3.2 Casing pressure hydro tests

16.3.2.1 General

16.3.2.1.1 The chloride content of liquids used to hydrotest austenitic stainless steel materials shall not exceed 50 mg/kg (wt ppm). To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

16.3.2.1.2 The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested (reference ASTM E 1003).

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

16.3.2.1.3 The vendor shall define test procedures for turbines with double shell construction.

16.3.2.2 Casing integrity test

16.3.2.2.1 All pressure-containing parts shall be hydro pressure tested to prove casing integrity with liquid at a gauge pressure of at least 1,5 times the maximum allowable working pressure but not less than 140 kPa (1,4 bar) (20 psi). See 3.17.

16.3.2.2.2 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydro test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the rated operating temperature. The stress values used shall be determined in accordance with 7.1.2. The pressure thus obtained shall then be the minimum pressure at which the hydro test shall be performed. The data sheets shall list actual hydro test pressures.

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

16.3.2.2.3 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The pressure casing integrity hydro test shall be considered satisfactory when neither leaks nor seepage through the casing is observed for a minimum of 30 min. Large, heavy castings may require a longer testing period to be agreed upon by the purchaser and the vendor. Seepage past internal test closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

NOTE The purpose of the pressure hydro test is to prove pressure casing integrity and not to prove joint sealing.

16.3.2.2.4 Use of a sealant compound or gasket on the casing joints is acceptable during the casing integrity hydro test.

16.3.2.3 Casing joint leakage test

A hydro test for casing joint leakage shall be performed. The hydro test pressure shall be 1,5 times the maximum allowable working pressure in that pressure zone. Temperature corrections as specified in 16.3.2.2.2 are not required for this test. This test should be performed after the casing hydro integrity test. Gaskets shall not be used at the casing joint for this test. Suitable joint compound may be used (see 7.1.6). The test shall be considered satisfactory when neither leaks nor seepage through the casing joint is observed for a minimum of 30 min. The casing joint leakage test may be combined with the casing hydro integrity test, provided casing joint gaskets are not used.

16.3.3 Mechanical running test

16.3.3.1 The requirements of a) to j), as follows, shall be met before the mechanical running test is performed.

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

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

c) Test-stand oil filtration shall be 10 µm nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10438 before any test is started.

NOTE For the purpose of this provision, API 614 is equivalent to ISO 10438.

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

e) All warning, protective and control devices used during the test shall be checked, and adjustments shall be made as required.

f) The mechanical running test shall be performed with the contract half coupling and a coupling mass simulator, or moment simulator, in accordance with ISO 10441 or API Std 671, in place (15.1.7).

g) All contract vibration probes, cables, oscillator-demodulators and accelerometers shall be in use during the test.

h) Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting revolutions per minute, peak-to-peak displacement and phase angle (x-y-y'). Presentation of vibration displacement and phase marker shall also be by oscilloscope.

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

j) If external housing vibration test values are specified, vibration data (minimum and maximum values and phase angles) shall be measured vertically and horizontally transverse to each bearing centreline using shop instrumentation.

16.3.3.2 Unless otherwise specified, operation of the control systems shall be demonstrated and the mechanical running test of the steam turbine shall be conducted as specified in a) to f), as follows.

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

a) Operate the equipment at speed increments of approximately 10 % from zero to the maximum continuous speed (avoiding any resonant speeds) and run at maximum continuous speed until bearings, lube-oil temperatures and shaft vibrations have stabilized.

b) Increase the speed to trip speed and run the equipment for a minimum of 15 min.

c) Check overspeed trip devices and adjust them until values within 1 % of the nominal trip setting are attained. Mechanical overspeed devices, when supplied, shall attain three consecutive non-trending trip values that meet this criterion.

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

e) Record data for governors such that it includes at least the sensitivity and linearity of relationship between speed and control signal, and, for adjustable governors, the response speed range.

f) Run the turbine continuously at the maximum continuous speed for at least 4 h.

16.3.3.3 During the mechanical running test, the requirements specified in a) to g), as follows, shall be met.

a) The mechanical operation of all equipment being tested, including all casing joints and connections, and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 9.6.8 and shall be recorded throughout the operating speed range.

b) While the equipment is operating at maximum continuous speed and at other speeds and/or load that may have been specified in the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous. As a minimum, this data shall cover a frequency range from 0,05 times to 8 times the maximum continuous speed. If the amplitude of any discrete, non-synchronous vibration exceeds 20 % of the allowable vibration as defined in 9.6.8, the purchaser and the vendor shall agree on requirements for any additional testing and on the equipment's acceptability.

c) The mechanical running test shall verify that lateral critical speeds conform to the requirements of 9.2 and 9.3. Any non-critically-damped critical speed below the trip speed shall be determined during the mechanical running test.

d) Shop verification of the unbalanced response analysis shall be performed in accordance with 9.3.

● e) Real-time vibration data, as agreed upon by the purchaser and vendor, shall be recorded and a copy provided to the purchaser.

f) Plots showing synchronous vibration amplitude and phase angle versus speed for deceleration shall be made before and after the 4 h run. Plots shall be made of both the filtered (one for each revolution) and unfiltered vibration levels. If specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be from the specified trip speed to 400 r/min.

g) During the 4 h test, lube-oil inlet pressures and temperatures shall be varied through the range specified in the steam turbine operating manual.

16.3.3.4 Unless otherwise specified, the requirements of a) to c), as follows shall be met after the mechanical running test is completed.

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

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

c) When spare rotors are ordered to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with this International Standard.

16.3.4 Optional tests and inspections

16.3.4.1 General

The purchaser shall specify in the inquiry or in the order whether any of the shop tests specified in 16.3.4.2 to 16.3.4.11 shall be performed.

16.3.4.2 Performance test

- The machine shall be tested in accordance with IEC 60953 or ASME PTC 6. If this is not practicable, the vendor’s proposal shall define the conditions under which the vendor proposes to conduct the test. Methodology and acceptance criteria shall be agreed upon by the purchaser and the vendor. Vibration levels shall be measured and recorded during this test, as specified in 16.3.3.1 and 16.3.3.2.

16.3.4.3 Complete unit test

- Components such as compressors, gears, drivers and auxiliaries, which make up a complete unit, shall be tested together. By agreement, this test may incorporate the mechanical running test.

16.3.4.4 Auxiliary equipment test

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

16.3.4.5 Post-test internal inspection of casing

- The steam turbine shall be dismantled, inspected and reassembled after satisfactory completion of the mechanical running test.

The merits of post-test internal inspection of casing should be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

16.3.4.6 Overspeed shutdown systems test

- The response time of the overspeed shutdown systems shall be recorded to confirm compliance with the requirements of 12.3.1.1.

16.3.4.7 Spare parts test

- Spare parts such as couplings, gears, diaphragms, bearings and seals shall be tested as specified by the purchaser.

See 16.3.3.4 c) for a mechanical test of the spare rotor.

16.3.4.8 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.

16.3.4.9 Trip valve test

- Complete valve assembly shall be tested by the vendor in its specified orientation and tripped closed from the full open position. Travel versus time shall be recorded. The trip time shall not exceed the required trip time (see 12.3.4.7).

16.3.4.10 Governor system response test

- If a load test is performed at a specific operating point, the response time of the turbine governing system shall be continuously recorded to confirm compliance with the requirements of 12.2.4.

16.3.4.11 Sound level test

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

Sound pressure levels may be converted into sound power levels in accordance with ISO 10494.

16.4 Preparation for shipment

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

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

16.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in a) to k), as follows.

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

   NOTE Austenitic stainless steels typically are not painted.

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

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

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

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

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

   NOTE These are shipping plugs; permanent plugs are covered in 7.2.6.

g) Turbines supplied without self-supporting baseplates shall be bolted to a shipping skid formed of heavy timbers suitable for sling-lift or forklift truck handling. Larger turbines shall have supports as required by the type of transportation and handling.

h) Lifting points, lifting lugs, and the centre of gravity shall be clearly identified on the equipment package. The vendor shall provide the recommended lifting arrangement.

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

● j) If a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 10 years. The rotor shall be crated for domestic or export shipment, as specified. Lead sheeting, at least 3 mm (1/8 in) thick or a purchaser-approved equivalent shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals. Unless otherwise specified, the rotor shall be prepared for vertical storage. It shall be supported from its coupling end with a fixture designed to support 1,5 times the rotor's mass without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation and maintenance manuals.

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

16.4.4 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped, matchmarked (for ease of reassembly), and permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

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

16.4.6 One copy of the manufacturer's installation instructions shall be packed and shipped with the turbine.

16.4.7 Connections on auxiliary piping, removed for shipment, shall be tagged and matchmarked for ease of reassembly.

16.4.8 The fit-up and assembly of machine-mounted piping shall be completed in the vendor's shop prior to shipment, to confirm fitup.

17 Vendor's information

17.1 General

17.1.1 The information to be furnished by the vendor is specified in 17.2 and 17.3. The vendor shall complete and forward a vendor drawing and data requirements form (see typical form in Annex J) or purchaser's equivalent to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

17.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

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

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

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

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

17.1.3 A coordination meeting shall be held, preferably at the vendor's plant, within four to six weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute a proposed agenda prior to this meeting, which shall include, but not be limited to, review of the following items:

a) the purchase order, scope of supply, unit responsibility, and subvendor items;

b) the data sheets;

c) applicable specifications and previously agreed-upon exceptions;

d) schedules for transmittal of data, production and testing;

e) the quality assurance program and procedures;

f) inspection, expediting and testing;

g) schematics and bills of material for auxiliary systems;

h) the physical orientation of the equipment, piping and auxiliary systems;

i) coupling selections;

j) thrust and journal bearing sizing, estimated loading and specific configurations;

k) the preliminary rotor dynamics analysis;

l) equipment performance, alternate operating conditions, startup, shutdown and any operating limitations;

m) instrumentation and controls.

17.2 Proposals

17.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. The proposal shall include, as a minimum, the data specified in 17.2.2 to 17.2.4, and a specific statement that the equipment and all its components and auxiliaries are in strict accordance with this International Standard. If the equipment or any of its components or auxiliaries is not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 17.1.2.

17.2.2 Drawings

The drawings indicated on the VDDR form shall be included in the proposal. As a minimum, the following data shall be included:

a) preliminary general arrangement or outline drawing for each turbine or skid-mounted package, showing overall dimensions, maintenance clearance dimensions, overall masses, erection masses, and the largest maintenance mass for each item, as well as the direction of rotation and the size and location of major purchaser connections;

b) cross-sectional drawings and/or literature showing the details of the proposed equipment;

c) schematics of all auxiliary systems, including the steam, lube-oil, control, and alarm and shutdown systems;

d) sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries [this information may be included on the drawings specified in 17.2.2 a)].

17.2.3 Technical data

The following data shall be included in the proposal:

a) the purchaser's data sheets, with complete vendor's information entered thereon;

b) the predicted noise data (see 6.1.15);

c) the VDDR form, indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the purchase order;

d) a list of spare parts recommended for start-up and normal maintenance purposes;

e) a list of the special tools furnished for maintenance;

f) a description of any special weather protection and winterization required for startup, operation and periods of idleness under the site conditions specified on the data sheets; this description shall show the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply;

g) a complete tabulation of utility requirements, e.g. steam, water, electricity, air and lube oil (including the quantity and supply pressure of 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 defined and clearly identified as such);

h) a description of any optional or additional tests and inspection procedures for materials, in accordance with 16.3.4;

i) a description of any special requirements specified in the purchaser's inquiry and in accordance with 11.1.2, 12.4, 14.2 and 15.4;

j) 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;

k) any startup, shutdown or operating restrictions required to protect the integrity of the equipment;

l) the expected output power at normal steam conditions and rated speed with governor control valves fully open;

m) 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 (for example, valve, nozzle, diaphragm, or blade changes with no changes to the rotor or casing);

n) a list of all relief valves in accordance with 15.4, including size and set pressure — relief valves furnished by the vendor shall also be specified, with valve manufacturer and model data provided;

o) a list of any components that can be construed as being of alternate design, hence requiring purchaser's acceptance;

p) the types of fasteners (e.g. SI or US Customary) used in equipment, including auxiliaries, in the vendor's scope of supply.

17.2.4 Curves

The vendor shall provide complete performance curves to encompass the map of operations, with any limitations indicated thereon. The curves shall include those indicated by the purchaser on the VDDR form.

17.3 Contract data

17.3.1 General

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

17.3.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, identification data specified in 17.1.2, revision number and date and title. Similar information shall be provided on all other documents.

17.3.1.3 Review of vendor data by the purchaser, with or without comment, shall not relieve the vendor of the responsibility of supplying the equipment in accordance with the purchase order.

17.3.1.4 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers and a schedule for transmission of each item listed. This list shall cross-reference data with the VDDR form in the purchase order.

17.3.2 Drawings and technical data

The drawings and data furnished by the vendor shall contain sufficient information so that, together with the manuals specified in 17.3.4, the purchaser can properly install, operate and maintain the equipment covered by the purchase order. All contract drawings and data shall be clearly legible (8 point minimum font size even if reduced from a larger size drawing), and shall cover the scope of the agreed VDDR form (see 17.1.1).

17.3.3 Parts lists and recommended spares

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

17.3.3.2 The vendor shall indicate all those parts that are recommended as start-up or maintenance spares, and the recommended stocking quantities of each. These should include spare parts recommendations of subsuppliers that were not available for inclusion in the vendor's original proposal. The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up.

17.3.4 Installation, operation, maintenance and technical manuals

17.3.4.1 General

The vendor shall provide sufficient written instructions and all necessary drawings to enable the purchaser to install, operate and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 17.1.2, an index sheet and a complete list of enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. “Typical” manuals are unacceptable.

17.3.4.2 Installation manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions. This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centres of mass, rigging provisions and procedures, and all installation data. All drawings and data specified in 17.2.2 and 17.2.3 that are pertinent to proper installation shall be included as part of this manual (see description of Item mm in Annex J).

17.3.4.3 Operating and maintenance manual

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

17.3.4.4 Technical data manual

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

Annex A
(informative)

Typical data sheets

This annex contains typical data sheets for use by the purchaser and the vendor.

The sheets are presented in SI units (10 sheets) and USC units (10 sheets).

Unless indicated otherwise, all pressure units are gauge pressure.

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS	JOB NO. ____ ITEM NO. ____ PURCHASE ORDER NO. ____ SPECIFICATION NO. ____ REVISION NO. ____ DATE ____ PAGE 1 OF 10 BY ____

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ☐ AS-BUILT

FOR ____ UNIT ____

SITE ____ SERIAL NUMBER ____

SERVICE ____ NUMBER REQUIRED ____

MANUFACTURER ____ MODEL ____ DRIVEN EQUIPMENT ITEM NO. ____

DRIVEN EQUIPMENT TYPE: ○ COMPRESSOR ○ GENERATOR ○ OTHER ____

NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ☐ PURCHASER OR MANUFACTURER

PERFORMANCE

OPERATING POINTS	SHAFT		INLET			INDUCTION/EXTRACTION			EXHAUST		
☐ ☐ AS APPLICABLE	POWER kW	SPEED r/min	FLOW kg/h	PRESS kPa	TEMP °C (TT)	FLOW kg/h	PRESS kPa	TEMP °C (TT)	PRESS kPa	TEMP °C (TT)	ENTHALPY kJ / kg
RATED											
NORMAL (3.26)(6.1.4)											
MINIMUM											

☐ STEAM RATE, kg/kW.h (3.44): ____ NORMAL ____ RATED

☐ POTENTIAL MAXIMUM POWER(3.30)

INDUCTION ○ CONTROLLED ○ UNCONTROLLED

EXTRACTION ○ CONTROLLED ○ UNCONTROLLED

STEAM CONDITIONS

		☐ INLET	☐ EXHAUST	☐ EXTRACTION INDUCTION	☐ EXTRACTION INDUCTION	☐ EXTRACTION INDUCTION
FLOW kg/h	MAXIMUM					
	NORMAL					
	MINIMUM					
PRESSURE kPa	MAXIMUM					
	NORMAL					
	MINIMUM					
TEMPERATURE °C (TT)	MAXIMUM					
	NORMAL					
	MINIMUM					

SITE AND UTILITY DATA

LOCATION:

○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR

○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE

○ OTHER: ____

○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D

○ LOW TEMPERATURE ○ CORROSIVE AGENTS

○ ELECTRICAL AREA CLASSIFICATION:

CLASS ____ GROUP ____ DIVISION ____

ZONE ____ GROUP ____ TEMPERATURE RATING: ____

SITE DATA:

○ ELEVATION ____ m ○ BAROM. PRESS ____ kPa

○ WINTER TEMP. ____ °C SUMMER TEMP. ____ °C

○ REL. HUMIDITY ____ % DESIGN WET BULB ____ °C

○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES

○ OTHER ____

UTILITY CONDITIONS:

○ AUXILIARY STEAM:	MAX	NORM	MIN
INITIAL PRESS.(kPa))			
INITIAL TEMPERATURE, °C (TT)			
EXH. PRESS. (kPa)			

INST. AIR (kPa): NORM ____ MIN ____ MAX ____

INSTRUMENT AIR DEW POINT: ____ °C

○ **ELECTRIC:**	DRIVERS	HEATING	INSTRUMENT/ CONTROL	ALARM/ SHUTDOWN
VOLTS				
PHASE				
HERTZ				
kW AVAILABLE				

○ **COOLING WATER:**

INLET TEMPERATURE: ____ °C MAXIMUM RETURN ____ °C

PRESS. NORM.: ____ kPa DESIGN ____ kPa

MINIMUM RETURN PRESSURE: ____ kPa

MAXIMUM ALLOWABLE PRESS. DROP: ____ kPa

WATER SOURCE ____

VELOCITY, m/s: MIN ____ MAX ____

FOULING FACTOR: ____ $m^2 \cdot K/kW$

○ **UTILITY CONSUMPTION:**

COOLING WATER: ____ m^3/h INST. AIR ____ m^3/h

AUX. STM: NORMAL ____ kg/h MAXIMUM ____ kg/h

AUX. DRIVERS: ELECTRIC ____ kW STEAM ____ kW

HEATER(S): ____ kW OTHER: ____

REMARKS: ____

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 2 OF 10 BY ______

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS

APPLICABLE SPECIFICATIONS:

ISO 10437 (API 612), SPECIAL PURPOSE STEAM TURBINES
○ OTHER ______
○ VENDOR HAVING UNIT RESPONSIBILITY(3.47): ______
○ GOVERNING SPECIFICATION, IF DIFFERENT: ______

NOISE SPECIFICATIONS:

○ APPLICABLE TO MACHINE:
SEE SPECIFICATION: ______
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION: ______
ACOUSTICAL TREATMENT ○ YES ○ NO
TYPE ______

CONSTRUCTION FEATURES

TURBINE TYPE ○ BACKPRESSURE ○ CONDENSING ○ INDUCTION ○ EXTRACTION ○ OTHER

☐ SPEEDS:
MAXIMUM CONTINUOUS ______ r/min TRIP ______ r/min
MAXIMUM ALLOWABLE ______ r/min

☐ LATERAL CRITICAL SPEEDS (DAMPED)(9.2)
FIRST CRITICAL ______ r/min ______ MODE
SECOND CRITICAL ______ r/min ______ MODE
THIRD CRITICAL ______ r/min ______ MODE
FOURTH CRITICAL ______ r/min ______ MODE

☐ VIBRATION ______ µm (PEAK TO PEAK)

☐ TORSIONAL CRITICAL SPEEDS (9.5):
FIRST CRITICAL ______ r/min
SECOND CRITICAL ______ r/min
THIRD CRITICAL ______ r/min
FOURTH CRITICAL ______ r/min
○ LATERAL ANALYSIS REPORT REQUIRED
○ INDIVIDUAL BODY ○ TRAIN
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED
☐ TRAIN TORSIONAL PERFORMED BY

☐ **CASINGS, NOZZLES & DIAPHRAGMS**

☐ MAWP (3.17)(7.1.3)
INLET SECTION ______ EXH. SECTION ______ (kPa)
INDUCTION / EXTRACT. SECTION ______ (kPa)
OTHER ______ (kPa)

☐ MAX OPERATING TEMP. (3.16)(3.21)
INLET SECTION ______ °C EXHAUST SECTION ______ °C
INDUCTION / EXTRACTION SECTION ______ °C

○ MINIMUM DESIGN METAL TEMPERATURE(11.1.15) ______ °C

○ RELIEF VALVE SETTING: INLET ______ (kPa) ______ (kPa)
EXTRACTION ______ (kPa) OTHER ______ (kPa)

☐ HYDRO TEST PRESSURE (16.3.2.2)
HP CASING ______ MID CASING ______ (kPa)
EXHAUSTCASING ______ OTHER ______ (kPa)
○ WELDED NOZZLE RING (7.3.1) NOZZLE RING ______ %ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST
☐ WELDED (7.3.2) ☐ OTHER ______
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	☐ SIZE	☐ FACING	○ POSTION	○ FLANGED OR STUDDED (7.2.1)(7.2.3)	○ MATING FLG. & GASKET BY VENDOR (7.2.7.d)	☐ MAXIMUM STEAM FLOW kg/h	☐ MINIMUM STEAM FLOW kg/h
INLET							
EXHAUST							
EXTRACTION							
INDUCTION							

AUX. SCRWD. PIPE CONN.: ○ TAPERED ○ STRAIGHT ○ MAIN CASING JOINT STUDS / NUTS DESIGNED FOR HYD. TENSIONING (7.1.15.f)

☐ **ALLOWABLE FORCES & MOMENTS**

	INLET		EXHAUST		EXTRACT. / INDUCT.	
	FORCE	MOMENT	FORCE	MOMENT	FORCE	MOMENT
	N	N·m	N	N·m	N	N·m
PARALLEL TO SHAFT						
VERTICAL						
HORZ. 90°						

ROTATION:(VIEWED FROM INLET END)

○ CW ○ CCW

SPECIAL-PURPOSE STEAM TURBINE
DATA SHEET
SI UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 3 OF 10 BY ______

MATERIALS-CASINGS & APPURTENANCES:

☐ HIGH PRESSURE CASING ______
☐ MID PRESSURE CASING ______
☐ EXHAUST CASING ______
☐ STEAM CHEST ______
☐ NOZZLE RING ______
○ STEAM CONTAMINANTS (11.1.6) ______
○ STEAM PATH COMPONENTS < HRC 22 (11.1.9)

☐ DIAPHRAGM/BLADE CARRIERS ______
☐ DIAPHRAGM NOZZLES ______
☐ OTHER ______

ROTATING ELEMENTS (8)

SHAFT TYPE:
☐ INTEGRAL WHEELS ☐ BUILT-UP (8.1.2) ☐ COMBINATION
☐ DOUBLE EXTENDED
☐ NUMBER OF STAGES ______ BEARING SPAN ______ mm
☐ SHAFT MATERIAL ______
BLADES(BUCKETS): ☐ MAX TIP SPEED ______ m/s
☐ FINAL STAGE BLADE LENGTH ______ mm MAX. ______ mm

☐ SHAFT ENDS: DIAMETER @ COUPLING ______ mm
○ STRAIGHT ○ TAPER ______ mm/m
○ KEYED ○ SINGLE ○ DOUBLE
○ HYDRAULIC FIT ○ INTEGRAL FLANGE
○ FIELD BALANCING PROVISIONS REQUIRED (8.1.4)
☐ DESCRIPTION OF FIELD BALANCING PROVISIONS: ______

REMARKS: ______

	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE
☐ WHEEL MATERIAL							
☐ BLADE MATERIAL							
☐ BLADE ROOT TYPE							
☐ CLOSURE PIECE TYPE							
☐ TIE WIRE MATERIAL							
☐ SHROUD MATERIAL							
☐ SHROUD ATTACH.							
☐ PITCH DIAMETER, mm.							
☐ BLADE HEIGHT, mm.							
☐ BLADE TYPE							
☐ ______							
☐ ______							

SHAFT SEALS (10.5)

	INLET	EXHAUST
☐ MAX. SEAL PRESSURE, kPa		
☐ STEAM LEAKAGE, kg/h		
☐ AIR LEAKAGE, m^3/h (std cond.)		
☐ SHAFT DIA. @ SEAL, mm		
☐ STATIONARY LABY. TYPE		
☐ ROTATING LABY. TYPE		
☐ MATERIAL		
☐		
☐		
☐ ______		

CASING END SEALS (10.5.1)

TYPE: ○ LABYRINTH (10.5.1) ○ OTHER ______
MATERIAL: ______

INTERSTAGE SEALS (10.5.2):

TYPE: ○ LABYRINTH
○ OTHER ______
MATERIAL: ______

REMARKS: ______

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 4 OF 10 BY ______

BEARINGS AND BEARING HOUSINGS

RADIAL (10.1.1)(10.1.2)

	INLET	EXHAUST
TYPE		
MANUFACTURER		
LENGTH (mm)		
SHAFT DIAMETER (mm)		
UNIT LOAD (ACT/ALLOW), N		
BASE MATERIAL		
BABBIT THICKNESS (mm)		
NUMBER OF PADS		
LOAD: BETWEEN/ON PAD		
PIVOT: CENTER/OFFSET %		
______		
______		

THRUST (10.2.1)(10.2.2)

	ACTIVE	INACTIVE
TYPE		
MANUFACTURER		
UNIT LOADING MAX. (MPa)		
UNIT LOAD ULTIMATE (MPa)		
NUMBER OF PADS		
AREA (mm²)		
PIVOT: CENTER / OFFSET, %		
PAD BASE MATERIAL		

LUBRICATION: ○ FLOODED ○ DIRECTED
THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE

BEARING TEMPERATURE DEVICES:

○ THERMOCOUPLES ○ TYPE ______
○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______
○ RESISTANCE TEMPERATURE DETECTORS
○ RESISTANCE MATERIAL ______ ☐ ______ ohm
○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______ MFR
○ LOCATION-JOURNAL BEARING
TOTAL ______ LOCATION ______
SCALE RANGE ______ ALARM SET @ ______ °C
SHUTDOWN SET @ ______ °C DELAY ______ s
○ LOCATION-THRUST BEARING
ACTIVE SIDE
TOTAL ______ LOCATION ______
INACTIVE SIDE
TOTAL ______ LOCATION ______
SCALE RANGE ______ ALARM SET @ ______ °C
SHUTDOWN SET @ ______ °C DELAY ______ s
○ MONITOR SUPPLIED BY: ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______

VIBRATION DETECTORS:

○ TYPE ______ ☐ MODEL ______
○ MANUFACTURER ______
○ NUMBER AT EACH SHAFT BRG ______ TOTAL NUMBER ______
MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ ALARM ☐ SET @ ______ µm
○ SHUTDOWN: ☐ SET @ ______ µm ○ DELAY ______ s

AXIAL POSITION DETECTORS:

☐ TYPE ______ ☐ MODEL ______
○ MFR ______ ○ NUMBER REQUIRED ______
MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ ALARM ☐ SET @ ______ µm
○ SHUTDOWN ☐ SET @ ______ µm ○ DELAY ______ s
○ PROVISION FOR ACCELEROMETER MOUNTED ON BRG HOUSINGS
KEYPHASOR : STEAM TURBINE GEAR DRIVEN EQUIP.
REMARKS: ______

LUBRICATION AND CONTROL OIL SYSTEM (15.5)

REFRENCE SPECIFICATIONS: ______
FURNISHED BY ○ TURBINE MFR ☐ OTHERS
○ SEPARATE FOR TURBINE ONLY
☐ COMMON W/ DRIVEN EQUIPMENT & INCL (15.5.2)(15.5.5):

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

OIL REQUIREMENTS:	CTRL OIL	LUBE OIL
NOMINAL FLOW, m^3/h		
TRANSIENT FLOW, m^3/h		
PRESSURE, kPa		
TEMPERATURE, °C		
TOT. HEAT REJ, MW		
OIL TYPE, Hydrocarbon/Synthetic		
VISCOSITY, SSU @ 37.8°C		
FILTRATION, µm		
______		
______		
______		

SPECIAL-PURPOSE STEAM TURBINE
DATA SHEET
SI UNITS

JOB NO. ________ ITEM NO. ________
REVISION NO. ________ DATE ________
PAGE 5 OF 10 BY ________

ACCESSORIES

COUPLINGS AND GUARDS (15.1.1)(15.1.2)

NOTE: SEE ROTATING ELEMENTS-SHAFT ENDS
○ SEE ATTACHED ISO 10441 DATA SHEET
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(15.1.8)
○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (15.1.6)(15.1.7)
LUBRICATION REQUIREMENTS
○ GREASE ○ CONT. OIL LUBE ○ NONE
☐ QUANTITY PER HUB ________ kg OR m^3/h

MOUNTING PLATES (15.3)

BASEPLATES FURNISHED BY: ________ ________
○ UNDER TURBINE ONLY ○ OTHER(15.3.2.1) ________
○ OPEN ○ NON-SKID DECKING (15.3.2.8) ○ DRIP RIM
○ LEVELING PADS (15.3.2.3) ○ SUITABLE FOR OPTICAL ALIGN
○ SINGLE SECTION ○ MULTI-SECTION
○ COLUMN MOUNTING (15.3.2.2) ○ SUBPLATES REQ'D (15.3.2.7)
○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ________

SOLEPLATES FURNISHED BY: ________
THICKNESS ________ mm
○ SUBPLATES REQUIRED (15.3.2.7)
○ HOLD-DOWN BOLTS FURNISHED BY ________
○ EPOXY PRIMER VENDOR (15.3.1.7)
____
○ ANCHOR BOLTS FURNISHED BY (15.3.1.9): ________

GEAR UNIT(15.2)

FURNISHED BY: ________ ○ REFERENCE ISO 13691 ○ OTHER ________
SEE DATA SHEETS ________ ________

CONTROL AND INSTRUMENTATION (12.0)

INSTRUMENTS AND CONTROL PANELS SHALL BE IN ACCORDANCE WITH THE FOLLOWING ATTACHED DATA SHEETS:
○ ISO 10438, PAGES ________
○ API 670, PAGES ________
○ PURCHASER'S DATA SHEETS ________
____

PROTECTIVE DEVICES

	EXHAUST RELIEF VALVE (7.1.3)(15.4.1)(15.4.2)	EXTRACT./INDUCT. RELIEF VALVE (7.1.3)(15.4.1)(15.4.2)	VACUUM BREAKER (12.3.1.3)	NON-RETURN VALVE(S) (12.3.1.4)	THERMAL RELIEF VALVE(S) (15.4.4)
MOUNTING LOCATION				X	
SET RELIEF PRESSURE, kPa			X		
CAPACITY, kg/h STEAM			X		
VALVE MANUFACTURER					
VALVE TYPE					
VALVE SIZE/RATING					
FLANGE FACING (FF, RF)					
FURNISHED BY					
QUANTITY					

REMARKS: ________

SPECIAL-PURPOSE STEAM TURBINE **DATA SHEET** **SI UNITS**	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 6 OF 10 BY ______

1 ○ **TRIP** ○ **TRIP & THROTTLE VALVES (12.3.4)** ○ **DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (12.3.4.2)**

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 ______ LEAKOFF ______ 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):**

	LOCATION	MAIN INLET	INDUCTION	INDUCTION / EXTRACTION	INDUCTION / EXTRACTION	NOTES
14–15	LOCATION	MAIN INLET	INDUCTION	INDUCTION EXTRACTION	INDUCTION EXTRACTION	NOTES
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 (15.8)**	**MISCELLANEOUS**
33	○ TURNING GEAR REQUIRED (15.8.1)	○ START-UP ASSISTANCE ______ DAYS
34	○ FURNISHED BY ______	○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S
35	○ TYPE(15.8.5) ______ SPEED ______ r/min	PIPING AND FOUNDATION DRAWINGS
36	○ ENGAGEMENT(15.8.2)(15.8.3)(15.8.4): ○AUTO ○ MANUAL	○ VENDOR WITNESS INITIAL ALIGNMENT
37	○ MANUFACTURER ______ MODEL ______	☐ "Y" TYPE STRAINER
38	○ MOUNTED BY ______	☐ WATER WASHING CONNECTIONS
39	○ DRIVER: REFERENCE SPECIFICATION ______	○ STATIC CONDUCTING BRUSHES
40	DRIVEN BY: ○ELECTRIC MOTOR ○STEAM TURBINE	○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (12.3.1.3)
41	(15.8.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______	○ ______
42	○ OPERATOR STATION (15.8.7) ○ LOCAL ○ REMOTE	○ ______
43	**INSULATION & JACKETING (15.7)**	**SPECIAL TOOLS (15.9)**
44	○ BLANKET ○ OTHER ______	○ COUPLING RING AND PLUG GAUGE
45	○ JACKETING	○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
46	○ CARBON STEEL ○ STAINLESS STEEL	○ OTHER ______
47	○ EXTENT ______	☐ SPREADER BEAM(S)
48	______	○ ON LOAN
49	______	○ PURCHASE

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 7 OF 10 BY ______

GOVERNOR (12.2)

TYPE ◯ DIGITAL PROCESSOR BASED	◯ MANUFACTURER ______ MODEL ______
◯ OTHER ______	◯ SUPPLIED BY ______
◯ SIMPLEX ◯ MULTI-CPU	

STEAM TURBINE TYPE

◯ SINGLE VALVE SINGLE STAGE	◯ DOUBLE AUTOMATIC EXTRACTION
◯ SINGLE VALVE MULTISTAGE	◯ SINGLE AUTOMATIC EXTRACTION / INDUCTION
◯ MUTIVALVE MULTISTAGE	◯ DOUBLE AUTOMATIC EXTRACTION / INDUCTION
◯ SINGLE AUTO EXTRACTION	◯ OTHER ______

DRIVEN EQUIPMENT TYPE

◯ CENTRIFUGAL COMPRESSOR	◯ SYCHRONOUS GENERATOR
◯ AXIAL COMPRESSOR	◯ INDUCTION GENERATOR
◯ CENTRIFUGAL PUMP	◯ OTHER ______

SERVICE REQUIREMENTS

MECHANICAL DRIVE	GENERATOR DRIVE
◯ SPEED CONTROL BY:	◯ DROOP CONTROL
PROCESS VARIABLE ◯ PRESSURE ◯ FLOW	◯ FREQUENCY CONTROL
EXTRACTION ◯ PRESSURE ◯ FLOW	◯ LOAD CONTROL
INDUCTION ◯ PRESSURE ◯ FLOW	◯ KW CONTROL
TURBINE INLET ◯ PRESSURE ◯ FLOW	◯ KW IMPORT / EXPORT CONTROL
TURBINE EXHAUST ◯ PRESSURE ◯ FLOW	◯ LOAD SHEDDING
OTHER ______	◯ AUTOMATIC SYNCHRONIZATION
______	◯ AUTOMATIC VOLTAGE REGULATION
______	◯ TURBINE INLET PRESSURE LIMITING
	◯ INLET PRESSURE LIMITER

INPUT/OUTPUT REQUIREMENTS

DISCRETE INPUTS	DISCRETE OUTPUTS
◯ START OR RESET	◯ COMMON SHUTDOWN
◯ NORMAL STOP	◯ COMMON ALARM
◯ EMERGENCY TRIP	◯ OVERSPEED TRIP ______ r/min
◯ RAISE SPEED	◯ REMOTE SPEED SETPOINT ENABLED
◯ LOWER SPEED	◯ PRESSURE CONTROL ENABLED
◯ ENABLE/DISABLE REMOTE SPEED SETPOINT	◯ FLOW CONTROL ENABLED
◯ RAMP TO MINIMUM CONTINUOUS	◯ EXTRACTION CONTROL ENABLED
◯ OVERSPEED TEST ENABLE	◯ INDUCTION CONTROL ENABLED
◯ ENABLE PRESSURE CONTROL	◯ SPEED PICKUP ALARM
◯ ENABLE EXTRACTION CONTROL	◯ OTHER ______
◯ REMOTE ALARM CLEAR/ACKNOWLEDGE	
◯ ENABLE AUTO SYNCHRONIZE	
◯ CASCADE RAISE/LOWER	ANALOG OUTPUTS (4 mA to 20 mA)
◯ OTHER ______	◯ SPEED
ANALOG INPUTS (4 mA to 20 mA)	◯ SPEED SETPOINT
◯ REMOTE SET POINT	◯ REMOTE SPEED SETPOINT
◯ PROCESS PRESSURE	◯ EXTRACTION PRESSURE
◯ EXTRACTION ◯ PRESSURE ◯ FLOW	◯ EXTRACTION PRESSURE SETPOINT
◯ kW IND. LOAD ◯ PRESSURE ◯ FLOW	◯ ACTUATOR POSITION
◯ kW IMPORT / EXPORT	◯ PROCESS PRESSURE
◯ OTHER ______	◯ kW
______	◯ kW IMPORT/EXPORT
______	

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 8 OF 10 BY ______

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 SETPOINT ENABLE/DISABLE
○ RESET
○ OTHER ______

INPUTS TO PANEL FROM GOVERNOR
○ COMMON ALARM TRIP
○ TRIP LAMP
○ REMOTE SETPOINT ENABLED LAMP
○ SPEED SETPOINT METER
○ 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 ○ PROTOCOL ______
○ DISCRETE I/O
○ NETWORK TYPE ______

GOVERNOR SPEED PICKUP SENSORS(12.2.6):
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) ______

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 9 OF 10 BY ______

OVERSPEED SHUTDOWN SYSTEM (12.3)

○ FURNISHED BY ______	○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______
○ MANUFACTURER ______ ○ MODEL ______	○ SOLENOIDS SHALL: ○ DE-ENERGIZE TO TRIP
☐ ELECTRONIC, SET POINT ______ r/min	○ ENERGIZE TO TRIP
OVERSPEED SHUTDOWN REQUIREMENTS	○ CONTACTS SHALL BE: ○ NORMALLY OPEN
○ 2 OUT OF 3 VOTING LOGIC (12.3.2.1)	○ NORMALLY CLOSED
○ OTHER ______	○ VOLTAGE LEVEL: ______
______	______
______	

GLAND SEALING AND VACUUM SYSTEM(15.6)

SYSTEM PER: ○ ANNEX G.1 ○ ANNEX G.2	○ VACUUM SYSTEM FURNISHED BY ______
○ OTHER ______	○ SHIP LOOSE ○ SKID MOUNTED
○ AVAIL. HEADER PRESSURE ______ kPa TEMPERATURE ______ °C	○ OTHER ______
○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ kPa	○ GLAND CONDENSOR, SEE SPECIFICATION ______
○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE ______ °C	○ STEAM EJECTOR ○ ☐ STEAM PRESS. ______ kPa
☐ SEAL. STM. PRESS. ______ kPa ☐ FLOW ______ kg/h	☐ STEAM FLOW ______ kg/h
☐ SEALING STEAM RELIEF VALVE SET PRESSURE ______ kPa	○ VACUUM PUMP (15.6.2), SEE SPECIFICATION ______
○ FURNISHED BY ______	○ CONDENSATE RECEIVER
☐ FLOW ADJUSTING VALVES, TYPE ______	○ LOOP SEAL HEIGHT ______ m
○ FURNISHED BY ______	

INSPECTION AND TESTING (16.2) (16.3)

GENERAL

○ SHOP INSPECTION (16.1.4)

EXTENT: ______

○ REFERENCE INSPECTION CHECKLIST "I"

INSPECTION AND MATERIAL TESTING

○ FINAL ASSEMBLY RECORDS REQUIRED (16.2.1.1.f)

SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS

COMPONENT	MAG PART	DYE PEN	R.T.	U.T.	OBSVD	WIT
TRIP & T & T VALVE	○	○	○	○	○	○
STM CHEST	○	○	○	○	○	○
CASING	○	○	○	○	○	○
PIPING	○	○	○	○	○	○
ROTOR	○	○	○	○	○	○
					○	○

	OBSVD	WIT
○ HEAT STABILITY (16.2.2)	○	○
○ CLEANLINESS (16.2.3.3)	○	○
○ HARDNESS (16.2.3.4)	○	○
○ HYDRO TESTS (16.3.2)	○	○
○ BLADE SHAKER (STATIC)	○	○
ROTOR BALANCE ○ STANDARD (9.6.1)(9.6.2)	○	○
○ HIGH SPEED (9.6.3)	○	○
○ LOW SPEED PRIOR TO HIGH SPEED(9.6.6)	○	○
○ LOW SPEED RESIDUAL UNBALANCE CHECK(9.6.7)	○	○
○ FINAL SURFACE INSPECTION (16.4.3)	○	○
○ CRATING INSPECTION (16.4.1)	○	○
○ SPARE ROTOR FIT	○	○
○ CASING JOINT LEAK TEST (16.3.2.3)	○	○
○ ______	○	○

MECHANICAL RUNNING TEST (16.3.3)

	OBSVD	WIT
○ CONTRACT ROTOR	○	○
○ SPARE ROTOR	○	○
○ TEST W/JOB COUPLING	○	○
○ TEST TAPE RECORD REQUIRED	○	○
○ TEST TAPE GIVEN TO PURCH.	○	○
○ TEST W/JOB LUBE OIL CONSOLE	○	○
______	○	○

OPTIONAL TESTS (16.3.4)

	OBSVD	WIT
○ PERFORMANCE (16.3.4.2)	○	○
○ COMPLETE UNIT (16.3.4.3)	○	○
		○
AUXILIARY EQUIPMENT (16.3.4.4)		
○ TRIP/TRIP & THROTTLE VALVE	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ ______	○	○
○ CASING INTERNAL INSP (16.3.4.5)	○	○
○ COUPLING TO SHAFT FIT (ISO 10441)	○	○
○ TURNING GEAR	○	○
○ OVERSPEED SHUTDOWN SYSTEM	○	○
○ GOVERNOR RESPONSE (16.3.4.10)	○	○
○ SOUND (16.3.4.11)	○	○
○ SPARE PARTS TESTS (16.3.4.7)	○	○
○ ______	○	○
○ ______	○	○

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 10 OF 10 BY ______

MISCELLANEOUS

PAINTING	**WEIGHTS:**
○ MANUFACTURER'S STANDARD	☐ TURBINE ______ kg
○ OTHER ______	☐ ROTOR ______ kg
○ ______	☐ TURBINE UPPER HALF CASING ______ kg
UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI	☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ______ kg
SHIPMENT (16.4.1)(16.4.3.j)	☐ TRIP / TRIP & THROTTLE VALVE ______ kg
○ DOMESTIC ○ EXPORT	☐ MISCELLANEOUS ______ kg
○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS	☐ TOTAL SHIPPING MASS ______ kg
○ WATERPROOF BOXING REQUIRED	
○ SPARE ROTOR ASSEMBLY PACKAGED FOR:	
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE	
SPACE REQUIREMENTS:	**VENDOR DRAWING & DATA REQUIREMENTS (17)**
☐ COMPLETE UNIT: L ______ mm W ______ mm H ______ mm	○ ANNEX J
☐ CONTROL PANEL: L ______ mm W ______ mm H ______ mm	○ OTHER ______
☐ OTHER: L ______ mm W ______ mm H ______ mm	______
☐ OTHER: L ______ mm W ______ mm H ______ mm	______

REMARKS AND ADDITIONAL REQUIREMENTS:

SPECIAL-PURPOSE STEAM TURBINE **DATA SHEET** **US CUSTOMARY UNITS**	JOB NO. ____ ITEM NO. ____ PURCHASE ORDER NO. ____ 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 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ▢ PURCHASER OR MANUFACTURER

8 **PERFORMANCE**

		SHAFT		INLET			INDUCTION/EXTRACTION			EXHAUST		
9	OPERATING POINTS											
10	▢ AS APPLICABLE	POWER	SPEED	FLOW	PRESS	TEMP	FLOW	PRESS	TEMP	PRESS	TEMP	ENTHALPY
11		hp	r/min	lb/h	psig	°F (TT)	lb/h	psig	°F (TT)	psig/in HgA	°F (TT)	Btu/lb
12	RATED											
13	NORMAL (3.26) (6.1.4)											
14	MINIMUM											
15												

16 ☐ STEAM RATE, lb/hp-h (3.44): ____ NORMAL ____ RATED — INDUCTION ○ CONTROLLED ○ UNCONTROLLED
17 ☐ POTENTIAL MAXIMUM POWER (3.30) ____ — EXTRACTION ○ CONTROLLED ○ UNCONTROLLED

18 **STEAM CONDITIONS**

			▢ INLET	▢ EXHAUST	▢ EXTRACTION INDUCTION	▢ EXTRACTION INDUCTION	▢ EXTRACTION INDUCTION
19–20							
21		MAXIMUM					
22	FLOW	NORMAL					
23	lb/h	MINIMUM					
24		MAXIMUM					
25	PRESSURE	NORMAL					
26	psig	MINIMUM					
27		MAXIMUM					
28	TEMPERATURE	NORMAL					
29	°F (TT)	MINIMUM					

30 **SITE AND UTILITY DATA**

31 **LOCATION:**
32 ○ INDOOR ○ HEATED ○ UNDER ROOF ○ OUTDOOR
33 ○ UNHEATED ○ PARTIAL SIDES ○ GRADE ○ MEZZANINE
34 ○ OTHER: ____
35 ○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQ'D
36 ○ LOW TEMPERATURE ○ CORROSIVE AGENTS
37 ○ ELECTRICAL AREA CLASSIFICATION:
37 CLASS ____ GROUP ____ DIVISION ____
38 ZONE ____ GROUP ____ TEMPERATURE RATING: ____
39 **SITE DATA:**
40 ○ ELEVATION ____ FT ○ BAROM. PRESS ____ psia/HgA
41 ○ WINTER TEMP. ____ °F SUMMER TEMP. ____ °F
42 ○ REL. HUMIDITY ____ % DESIGN WET BULB ____ °F
43 ○ UNUSUAL CONDITIONS: ○ DUST ○ FUMES
44 ○ OTHER ____
45 **UTILITY CONDITIONS:**
46 ○ AUXILIARY STEAM: MAX NORM MIN
47 INITIAL PRESSURE (psig) ____ ____ ____
48 INITIAL TEMPERATURE, °F (TT) ____ ____ ____
49 EXHAUST PRESS. (psig/in HgA) ____ ____ ____
50 INSTRUMENT AIR (psig): NORM ____ MIN ____ MAX ____
51 INSTRUMENT AIR DEW POINT: °F

31 ○ **ELECTRIC:** DRIVERS HEATING INSTRUMENT/ ALARM/
32 CONTROL SHUTDOWN
33 VOLTS ____ ____ ____ ____
34 PHASE ____ ____ ____ ____
35 HERTZ ____ ____ ____ ____
36 KW AVAILABLE ____ ____ ____ ____
37 ○ **COOLING WATER:**
37 INLET TEMPERATURE: ____ °F MAXIMUM RETURN ____ °F
38 PRESSURE NORMAL: ____ psig DESIGN: ____ psig
39 MINIMUM RETURN PRESSURE: ____ psig
40 MAXIMUM ALLOWABLE PRESSURE DROP: ____ psi
41 WATER SOURCE ____
42 VELOCITY, FPS: MIN ____ MAX ____
43 FOULING FACTOR: ____ h·ft²·°R/Btu
44 ○ **UTILITY CONSUMPTION:**
45 COOLING WATER: ____ GPM INST. AIR ____ SCFM
46 AUX. STM: NORMAL ____ lb/h MAXIMUM ____ lb/h
47 AUX. DRIVERS: ELECTRIC ____ hp STEAM ____ hp
48 HEATER(S): ____ kW OTHER: ____

52 REMARKS: ____
52 ____

SPECIAL-PURPOSE STEAM TURBINE
DATA SHEET
US CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 2 OF 10 BY ______

APPLICABLE SPECIFICATIONS:
ISO 10437 (API 612), SPECIAL PURPOSE STEAM TURBINES
○ OTHER ______
______
○ VENDOR HAVING UNIT RESPONSIBILITY(3.47):
______
○ GOVERNING SPECIFICATION, IF DIFFERENT:
______

NOISE SPECIFICATIONS:
○ APPLICABLE TO MACHINE:
SEE SPECIFICATION: ______
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION: ______
ACOUSTICAL TREATMENT ○ YES ○ NO
TYPE ______

CONSTRUCTION FEATURES

TURBINE TYPE ○BACKPRESSURE ○ CONDENSING ○ INDUCTION ○ EXTRACTION ○ OTHER:

☐ SPEEDS:
MAXIMUM CONTINUOUS ______ r/min TRIP ______ r/min
MAXIMUM ALLOWABLE ______ r/min
☐ LATERAL CRITICAL SPEEDS (DAMPED)(9.2)
FIRST CRITICAL ______ r/min ______ MODE
SECOND CRITICAL ______ r/min ______ MODE
THIRD CRITICAL ______ r/min ______ MODE
FOURTH CRITICAL ______ r/min ______ MODE
☐ VIBRATION ______ mil (PEAK TO PEAK)

☐ TORSIONAL CRITICAL SPEEDS (9.5):
FIRST CRITICAL ______ r/min
SECOND CRITICAL ______ r/min
THIRD CRITICAL ______ r/min
FOURTH CRITICAL ______ r/min
○ LATERAL ANALYSIS REPORT REQUIRED
○ INDIVIDUAL BODY ○ TRAIN
○ UNDAMPED STIFFNESS MAP REQUIRED
○ TRAIN TORSIONAL ANALYSIS REPORT REQUIRED
☐ TRAIN TORSIONAL PERFORMED BY

☐ **CASINGS, NOZZLES & DIAPHRAGMS**

☐ MAWP (3.17) (7.1.3)
INLET SECTION ______ psig EXH. SECTION ______ psig
INDUCTION / EXTRACT. SECTION ______ psig
OTHER ______ psig
☐ MAX OPERATING TEMP. (3.16)(3.21)
INLET SECTION ______ °F EXHAUST SECTION ______ °F
INDUCTION / EXTRACTION SECTION ______ °F
○ MINIMUM DESIGN METAL TEMPERATURE(11.1.15) ______ °F
○ RELIEF VALVE SETTING: INLET ______ psig ______ psig
EXTRACTION ______ psig OTHER ______ psig

☐ HYDRO TEST PRESSURE (16.3.2.2)
HP CASING ______ psig MID CASING ______ psig
EXHAUST CASING ______ psig OTHER ______ psig
○ WELDED NOZZLE RING (7.3.1) NOZZLE RING ______ %ADM.
DIAPHRAGM BLADE ATTACH.: ☐ INTEGRALLY CAST
☐ WELDED (7.3.2) ☐ OTHER ______
DIAPHRAGM AXIAL LOCATION: ☐ INDIVIDUALLY ☐ STACKED

CASING CONNECTIONS

CONNECTION	☐ SIZE	☐ FACING	○ POSTION	☐ FLANGED OR STUDDED (7.2.1) (7.2.3)	○ MATING FLG. & GASKET BY VENDOR (7.2.7.d)	☐ MAXIMUM STEAM FLOW lb/h	☐ MINIMUM STEAM FLOW lb/h
INLET							
EXHAUST							
EXTRACTION							
INDUCTION							

AUX. SCRWD. PIPE CONN.: ○ TAPERED ○ STRAIGHT ○ MAIN CASING JOINT STUDS / NUTS DESIGNED FOR HYD. TENSIONING (7.1.15.f)

☐ **ALLOWABLE FORCES & MOMENTS**

	INLET		EXHAUST		EXTRACT. / INDUCT.	
	FORCE	MOMENT	FORCE	MOMENT	FORCE	MOMENT
	lb	ft-lb	lb	ft-lb	lb	ft-lb
PARALLEL TO SHAFT						
VERTICAL						
HORZ. 90°						

ROTATION:(VIEWED FROM INLET END)
○ CW ○ CCW

SPECIAL-PURPOSE STEAM TURBINE **DATA SHEET** **US CUSTOMARY UNITS**	JOB NO. ____ ITEM NO. ____ REVISION NO. ____ DATE ____ PAGE 3 OF 10 BY ____

MATERIALS-CASINGS & APPURTENANCES:

☐ HIGH PRESSURE CASING ____
☐ MID PRESSURE CASING ____
☐ EXHAUST CASING ____
☐ STEAM CHEST ____
☐ NOZZLE RING ____
○ STEAM CONTAMINANTS (11.1.6) ____
○ STEAM PATH COMPONENTS < HRC 22 (11.1.9)

☐ DIAPHRAGM/BLADE CARRIERS ____
☐ DIAPHRAGM NOZZLES ____
☐ OTHER ____

ROTATING ELEMENTS (8)

SHAFT TYPE:
☐ INTEGRAL WHEELS ☐ BUILT-UP (8.1.2) ☐ COMBINATION
☐ DOUBLE EXTENDED
☐ NUMBER OF STAGES ____ BEARING SPAN ____ in
☐ SHAFT MATERIAL ____
BLADES(BUCKETS): ☐ MAXIMUM TIP SPEED ____ ft/min
☐ FINAL STAGE BLADE LENGTH ____ in MAX. ____ in
REMARKS: ____

☐ SHAFT ENDS: DIAMETER @ COUPLING ____ in
○ STRAIGHT ○ TAPER ____ in/ft
○ KEYED ○ SINGLE ○ DOUBLE
○ HYDRAULIC FIT ○ INTEGRAL FLANGE
○ FIELD BALANCING PROVISIONS REQUIRED (8.1.4)
☐ DESCRIPTION OF FIELD BALANCING PROVISIONS: ____
REMARKS: ____

	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE	STAGE
☐ WHEEL MATERIAL							
☐ BLADE MATERIAL							
☐ BLADE ROOT TYPE							
☐ CLOSURE PIECE TYPE							
☐ TIE WIRE MATERIAL							
☐ SHROUD MATERIAL							
☐ SHROUD ATTACH.							
☐ PITCH DIAMETER, in							
☐ BLADE HEIGHT, in							
☐ BLADE TYPE							
☐ ____							
☐ ____							

SHAFT SEALS (10.5)

	INLET	EXHAUST
☐ MAX. SEAL PRESSURE, psig		
☐ STEAM LEAKAGE, lb/h		
☐ AIR LEAKAGE, SCFM		
☐ SHAFT DIAMETER @ SEAL, in		
☐ STATIONARY LABY. TYPE		
☐ ROTATING LABY. TYPE		
☐ MATERIAL		
☐		
☐		
☐ ____		

CASING END SEALS (10.5.1)

TYPE: ○ LABYRINTH (10.5.1) ○ OTHER ____
MATERIAL: ____

INTERSTAGE SEALS (10.5.2):

TYPE: ○ LABYRINTH
○ OTHER ____
MATERIAL: ____

REMARKS: ____

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET US CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 4 OF 10 BY ______

BEARINGS AND BEARING HOUSINGS

RADIAL (10.1.1)(10.1.2)

	INLET	EXHAUST
☐ TYPE		
☐ MANUFACTURER		
☐ LENGTH (IN)		
☐ SHAFT DIAMETER (IN)		
☐ UNIT LOAD (ACT/ALLOW)(PSI)		
☐ BASE MATERIAL		
☐ BABBIT THICKNESS (IN)		
☐ NUMBER OF PADS		
☐ LOAD: BETWEEN/ON PAD		
☐ PIVOT: CENTER/OFFSET %		
☐ ______		
☐ ______		

THRUST (10.2.1)(10.2.2)

	ACTIVE	INACTIVE
☐ TYPE		
☐ MANUFACTURER		
☐ UNIT LOADING MAX. (psi)		
☐ UNIT LOAD ULTIMATE (psi)		
☐ NUMBER OF PADS		
☐ AREA (IN²)		
☐ PIVOT: CENTER / OFFSET, %		
☐ PAD BASE MATERIAL		

LUBRICATION: ○ FLOODED ○ DIRECTED

THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE

BEARING TEMPERATURE DEVICES:

○ THERMOCOUPLES ○ TYPE ______

○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______

○ RESISTANCE TEMPERATURE DETECTORS

○ RESISTANCE MATERIAL ______ ☐ ______ ohm

○ SELECTOR SWITCH & INDICATOR BY: ______ PURCH ______ MFR

○ LOCATION-JOURNAL BEARING

TOTAL ______ LOCATION ______

SCALE RANGE ______ ALARM SET @ ______ °F

SHUTDOWN SET @ ______ °F DELAY ______ s

○ LOCATION-THRUST BEARING

ACTIVE SIDE

TOTAL ______ LOCATION ______

INACTIVE SIDE

TOTAL ______ LOCATION ______

SCALE RANGE ______ ALARM SET @ ______ °F

SHUTDOWN SET @ ______ °F DELAY ______ s

○ MONITOR SUPPLIED BY: ______

○ LOCATION ______ ENCLOSURE ______

○ MFR. ______ ☐ MODEL ______

VIBRATION DETECTORS:

○ TYPE ______ ☐ MODEL ______

○ MANUFACTURER ______ ______

○ NUMBER AT EACH SHAFT BRG ______ TOTAL NUMBER ______

MONITOR SUPPLIED BY ______

○ LOCATION ______ ENCLOSURE ______

○ MFR ______ ☐ MODEL ______

☐ SCALE RANGE ______ ALARM ☐ SET @ ______ mil

○ SHUTDOWN: ☐ SET @ ______ mil ○ DELAY ______ s

AXIAL POSITION DETECTORS:

☐ TYPE ______ ☐ MODEL ______

○ MFR ______ ○ NUMBER REQUIRED ______

MONITOR SUPPLIED BY ______

○ LOCATION ______ ENCLOSURE ______

○ MFR ______ ☐ MODEL ______

☐ SCALE RANGE ______ ALARM ☐ SET @ ______ mil

○ SHUTDOWN ☐ SET @ ______ mil ○ DELAY ______ s

○ PROVISION FOR ACCELEROMETER MOUNTED ON BRG HOUSINGS

KEYPHASOR : ○ STEAM TURBINE ○ GEAR ○ DRIVEN EQUIP.

REMARKS: ______

LUBRICATION AND CONTROL OIL SYSTEM (15.5)

REFERENCE SPECIFICATIONS: ______

FURNISHED BY ○ TURBINE MFR ☐ OTHERS

○ SEPARATE FOR TURBINE ONLY

☐ COMMON W/ DRIVEN EQUIPMENT & INCL (15.5.2) (15.5.5):

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

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		
☐ ______		
☐ ______		
☐ ______		

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET US CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 5 OF 10 BY ______

ACCESSORIES

COUPLINGS AND GUARDS (15.1.1)(15.1.2)

NOTE: SEE ROTATING ELEMENTS-SHAFT ENDS
○ SEE ATTACHED API 671 DATA SHEET
COUPLING FURNISHED BY ______
☐ MANUFACTURER ______ TYPE ______ MODEL ______
COUPLING GUARD FURNISHED BY ______
TYPE ○ FULLY ENCLOSED ○ SEMI OPEN ○ OTHER ______

COUPLING DETAILS
☐ MAXIMUM OUTER DIAMETER ______ in
☐ HUB WEIGHT ______ lb
☐ SPACER LENGTH ______ in
☐ SPACER MASS ______ lb

☐ VENDOR MOUNT HALF COUPLING (15.1.8)
○ MASS SIMULATOR / IDLING ADAPTER REQUIRED (15.1.6) (15.1.7)
LUBRICATION REQUIREMENTS
○ GREASE ○ CONT. OIL LUBE ○ NONE
☐ QUANTITY PER HUB ______ lb OR U.S. gal/min

MOUNTING PLATES (15.3)

BASEPLATES FURNISHED BY: ______
○ UNDER TURBINE ONLY ○ OTHER(15.3.2.1) ______
○ OPEN ○ NON-SKID DECKING (15.3.2.8) ○ DRIP RIM
○ LEVELING PADS (15.3.2.3) ○ SUITABLE FOR OPTICAL ALIGN
○ SINGLE SECTION ○ MULTI-SECTION
○ COLUMN MOUNTING (15.3.2.2) ○ SUBPLATES REQ'D (15.3.2.7)
○ LEVELING(CHOCK) BLOCKS REQD SUPPLIED BY: ______

SOLEPLATES FURNISHED BY: ______
THICKNESS ______ IN.
○ SUBPLATES REQUIRED (15.3.2.7)
○ HOLD-DOWN BOLTS FURNISHED BY ______
○ EPOXY PRIMER VENDOR (15.3.1.7)
○ ANCHOR BOLTS FURNISHED BY (15.3.1.9): ______

GEAR UNIT(15.2)

FURNISHED BY: ______ ○ REFERENCE API 613 ○ OTHER ______
○ SEE ATTACHED GEAR DATA SHEETS

CONTROL AND INSTRUMENTATION (12.0)

INSTRUMENTS AND CONTROL PANELS SHALL BE IN ACCORDANCE WITH THE FOLLOWING ATTACHED DATA SHEETS:
○ API-614 APPENDIX B, PAGES ______
○ API 670 APPENDIX D, PAGES ______
○ PURCHASER'S DATA SHEETS ______

PROTECTIVE DEVICES

	EXHAUST RELIEF VALVE (7.1.3)(15.4.1)(15.4.2)	EXTRACT./INDUCT. RELIEF VALVE (7.1.3)(15.4.1)(15.4.2)	VACUUM BREAKER (12.3.1.3)	NON-RETURN VALVE(S) (12.3.1.4)	THERMAL RELIEF VALVE(S) (15.4.4)
MOUNTING LOCATION				X	
SET RELIEF PRESSURE, psig			X		
CAPACITY, lb/h STEAM			X		
VALVE MANUFACTURER					
VALVE TYPE					
VALVE SIZE/RATING					
FLANGE FACING (FF, RF)					
FURNISHED BY					
QUANTITY					

REMARKS: ______

SPECIAL-PURPOSE STEAM TURBINE
DATA SHEET
US CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 6 OF 10 BY ______

○ TRIP ○ TRIP & THROTTLE VALVES (12.3.4) ○ DUPLICATE TRIP / TRIP AND THROTTLE VALVES REQUIRED (12.3.4.2)

LOCATION: ○ MAIN INLET ○ INDUCTION
PROVIDED BY: ○ VENDOR ○ PURCHASER
☐ MANUFACTURER ______ MODEL ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______
☐ SIZE ______ RATING ______ FACING ______

CONSTRUCTION FEATURES:	INLET	INDUCT.
RESET: ○ MANUAL ○ HYDRAULIC		
TRIP: ○ LOCAL (MANUAL) ○ REMOTE		
EXERCISER: ○ LOCAL (MANUAL) ○ REMOTE		
○ FULLY OIL OPERATED		

☐ STRAINER: OPENING SIZE ______ (in/MESH)
MATERIAL ______
○ TEMPORARY START-UP STRAINER ______ (MESH)
MATERIAL ______
☐ STEM MATERIAL ______ HARDNESS ______ HRC
☐ SEAT MATERIAL ______ HARDNESS ______ HRC
☐ PACKING MATERIAL ______ LEAKOFF ______ 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 (15.8)

○ TURNING GEAR REQUIRED (15.8.1)
○ FURNISHED BY ______
○ TYPE(15.8.5) ______ SPEED ______ r/min
○ ENGAGEMENT(15.8.2)(15.8.3)(15.8.4): ○ AUTO ○ MANUAL
○ MANUFACTURER ______ MODEL ______
○ MOUNTED BY ______
○ DRIVER: REFERENCE SPECIFICATION ______
DRIVEN BY: ○ ELECTRIC MOTOR ○ STEAM TURBINE
(15.8.5) ○ HYD./PNEU. MOTOR ○ OTHER: ______
○ OPERATOR STATION (15.8.7) ○ LOCAL ○ REMOTE

MISCELLANEOUS

○ START-UP ASSISTANCE ______ DAYS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING AND FOUNDATION DRAWINGS
○ VENDOR WITNESS INITIAL ALIGNMENT
☐ "Y" TYPE STRAINER
☐ WATER WASHING CONNECTIONS
○ STATIC CONDUCTING BRUSHES
○ SHUTDOWN ACTIVATES EXHAUST VACUUM BREAKER (12.3.1.3)
○ ______
○ ______

INSULATION & JACKETING (15.7)

○ BLANKET ○ OTHER ______
○ JACKETING
○ CARBON STEEL ○ STAINLESS STEEL
○ EXTENT ______
______
______

SPECIAL TOOLS (15.9)

○ COUPLING RING AND PLUG GAUGE
○ HYDRAULIC COUPLING MOUNTING/REMOVAL KIT
○ OTHER ______
☐ SPREADER BEAM(S)
○ ON LOAN
○ PURCHASE

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET US CUSTOMARY UNITS

JOB NO. ________ ITEM NO. ________
REVISION NO. ________ DATE ________
PAGE 7 OF 10 BY ________

GOVERNOR (12.2)

TYPE ○ DIGITAL PROCESSOR BASED
○ OTHER ________
○ SIMPLEX ○ MULTI-CPU

○ MANUFACTURER ________ MODEL ________
○ SUPPLIED BY ________

STEAM TURBINE TYPE

○ SINGLE VALVE SINGLE STAGE
○ SINGLE VALVE MULTISTAGE
○ MUTIVALVE MULTISTAGE
○ SINGLE AUTO EXTRACTION

○ DOUBLE AUTOMATIC EXTRACTION
○ SINGLE AUTOMATIC EXTRACTION / INDUCTION
○ DOUBLE AUTOMATIC EXTRACTION / INDUCTION
○ OTHER ________

DRIVEN EQUIPMENT TYPE

○ CENTRIFUGAL COMPRESSOR
○ AXIAL COMPRESSOR
○ CENTRIFUGAL PUMP

○ SYCHRONOUS GENERATOR
○ INDUCTION GENERATOR
○ OTHER ________

SERVICE REQUIREMENTS

MECHANICAL DRIVE

○ SPEED CONTROL BY:

PROCESS VARIABLE	○ PRESSURE	○ FLOW
EXTRACTION	○ PRESSURE	○ FLOW
INDUCTION	○ PRESSURE	○ FLOW
TURBINE INLET	○ PRESSURE	○ FLOW
TURBINE EXHAUST	○ PRESSURE	○ FLOW
OTHER	________	

____
____

GENERATOR DRIVE

○ DROOP CONTROL
○ FREQUENCY CONTROL
○ LOAD CONTROL
○ KW CONTROL
○ KW IMPORT / EXPORT CONTROL
○ LOAD SHEDDING
○ AUTOMATIC SYNCHRONIZATION
○ AUTOMATIC VOLTAGE REGULATION
○ TURBINE INLET PRESSURE LIMITING
○ INLET PRESSURE LIMITER

INPUT/OUTPUT REQUIREMENTS

DISCRETE INPUTS

○ START OR RESET
○ NORMAL STOP
○ EMERGENCY TRIP
○ RAISE SPEED
○ LOWER SPEED
○ ENABLE/DISABLE REMOTE SPEED SETPOINT
○ RAMP TO MINIMUM CONTINUOUS
○ OVERSPEED TEST ENABLE
○ ENABLE PRESSURE CONTROL
○ ENABLE EXTRACTION CONTROL
○ REMOTE ALARM CLEAR/ACKNOWLEDGE
○ ENABLE AUTO SYNCHRONIZE
○ CASCADE RAISE/LOWER
○ OTHER ________

ANALOG INPUTS (4 mA to 20 mA)

○ REMOTE SET POINT
○ PROCESS PRESSURE
○ EXTRACTION ○ PRESSURE ○ FLOW
○ kW IND. LOAD ○ PRESSURE ○ FLOW
○ kW IMPORT / EXPORT
○ OTHER ________
____
____

DISCRETE OUTPUTS

○ COMMON SHUTDOWN
○ COMMON ALARM
○ OVERSPEED TRIP ________ r/min
○ REMOTE SPEED SETPOINT ENABLED
○ PRESSURE CONTROL ENABLED
○ FLOW CONTROL ENABLED
○ EXTRACTION CONTROL ENABLED
○ INDUCTION CONTROL ENABLED
○ SPEED PICKUP ALARM
○ OTHER ________

ANALOG OUTPUTS (4 mA to 20 mA)

○ SPEED
○ SPEED SETPOINT
○ REMOTE SPEED SETPOINT
○ EXTRACTION PRESSURE
○ EXTRACTION PRESSURE SETPOINT
○ ACTUATOR POSITION
○ PROCESS PRESSURE
○ kW
○ kW IMPORT/EXPORT

SPECIAL-PURPOSE STEAM TURBINE
DATA SHEET
US CUSTOMARY UNITS

JOB NO. ________ ITEM NO. ________
REVISION NO. ________ DATE ________
PAGE 8 OF 10 BY ________

1 **GOVERNOR INSTALLATION REQUIREMENTS**
2 LOCATION ○ LOCAL (AT TURBINE) | MOUNTING ○ FLUSH MOUNT IN PANEL ○ SURFACE MOUNT
3 ○ REMOTE (CONTROL ROOM) | ○ VERTICAL RACK
4 ○ OTHER | POWER SOURCE SINGLE DUAL
5 ○ AREA CLASSIFICATION: | 120 V (a.c.) ○ ○
6 CLASS ___ GROUP ___ DIVISION ___ | 220 V (a.c.) ○ ○
7 ZONE ___ GROUP ___ TEMP. RATING: ___ | 125 V (d.c.) ○ ○
8 ENCLOSURE ○ IP65 | 24 V (d.c.) ○ ○
9 ○ NEMA 4 | ________ ○ ○
10 ○ NEMA 4X | ________ ○ ○
11 ○ OTHER ________
12 **LOCAL GOVERNOR CONTROL PANEL** ○ REQUIRED ○ NOT REQUIRED
13 LOCATION ○ LOCAL (AT TURBINE) | ENCLOSURE ○ IP65
14 ○ REMOTE CONTROL ROOM | ○ NEMA 4 ○ NEMA 4X
15 ○ OTHER ________ | ○ OTHER ________
16 | ○ AREA CLASIFICATION
17 OUTPUTS FROM PANEL TO GOVERNOR | CLASS ___ GROUP ___ DIVISION ___
18 ○ START | ZONE ___ GROUP ___ TEMP. RATING: ___
19 ○ TRIP | INPUTS TO PANEL FROM GOVERNOR
20 ○ RAISE | ○ COMMON ALARM TRIP
21 ○ LOWER | ○ TRIP LAMP
22 ○ OVERSPEED TEST | ○ REMOTE SETPOINT ENABLED LAMP
23 ○ RAMP TO MINIMUM CONTINUOUS | ○ SPEED SETPOINT METER
24 ○ REMOTE SETPOINT ENABLE/DISABLE | ○ OTHER ________
25 ○ RESET | ________
26 ○ OTHER ________ | ________
27 **MISCELLANEOUS GOVERNOR DETAILS**
28 GOVERNOR ACTION ON LOSS OF REMOTE SIGNAL: ○ LOCKS ON LAST VALUE
29 ○ GOES TO MINIMUM CONTINUOUS
30 ○ GOES TO MAXIMUM CONTINUOUS
31
32 EXTERNAL INTERFACE DEVICE TYPE: ○ PRINTER FORMAT: ○ GRAPHIC DISPLAY
33 ○ CRT ○ TABULAR DATA
34 ○ MODEM ○ TRENDING (REAL TIME)
35 ○ HISTORICAL ARCHIVING
36 ○ DISTRIBUTIVE CONTROL SYSTEM MANUFACTURER ________ ○ MODEL ________
37 DATA TRANSMISSION ○ DATA LINK ○ PROTOCOL ________
38 ○ DISCRETE I/O
39 ○ NETWORK TYPE ________
40
41 GOVERNOR SPEED PICKUP SENSORS(12.2.6):
42 MANUFACTURER ________ MODEL ________ INSTALLATION: ○ DUAL ○ TRIPLE ○ INSTALLED SPARE
43 ○ NUMBER OF TEETH IN SPEED SENSING SURFACE ________
44
45 ACTUATOR(S): ○ SUPPLIED BY ________ ○ MANUFACTURER ________ ○ MODEL ________
45 ACTUATOR TYPE ○ HYDRAULIC ○ PNEUMATIC ○ SINGLE COIL ○ MULTI COIL ○ OTHER ________
46
47 **TURBINE MOUNTED ACCESSORIES**
47 TACHOMETER ○ MANUFACTURER ________ ○ MODEL ________ ○ NUMBER REQUIRED. ________
48 ○ LOCATION(S) ________
49
50

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET US CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 9 OF 10 BY ______

OVERSPEED SHUTDOWN SYSTEM(12.3)

○ FURNISHED BY ______
○ MANUFACTURER ______ ○ MODEL ______
☐ ELECTRONIC, SET POINT ______ r/min
OVERSPEED SHUTDOWN REQUIREMENTS
○ 2 OUT OF 3 VOTING LOGIC (12.3.2.1)
○ OTHER ______

○ NUMBER OF TEETH IN SPEED SENSING SURFACE ______
○ SOLENOIDS SHALL: ○ DE-ENERGIZE TO TRIP ○ ENERGIZE TO TRIP
○ CONTACTS SHALL BE: ○ NORMALLY OPEN ○ NORMALLY CLOSED
○ VOLTAGE LEVEL: ______

GLAND SEALING AND VACUUM SYSTEM(15.6)

SYSTEM PER: ○ ANNEX G.1 ○ ANNEX G.2 ○ OTHER ______
○ AVAIL. HEADER PRESSURE ______ psig TEMPERATURE ______ °F
○ AVAILABLE SEAL STEAM SUPPLY PRESSURE ______ psig
○ AVAILABLE SEAL STEAM SUPPLY TEMPERATURE. ______ °F
☐ SEALING STEAM PRESSURE ______ psig ☐ FLOW ______ lb/h
☐ SEALING STEAM. RELIEF VALVE SET PRESSURE ______ psig
○ FURNISHED BY ______
☐ FLOW ADJUSTING VALVES, TYPE ______
○ FURNISHED BY ______

○ VACUUM SYSTEM FURNISHED BY ______
○ SHIP LOOSE ○ SKID MOUNTED
○ OTHER ______
○ GLAND CONDENSOR, SEE SPECIFICATION ______
○ STEAM EJECTOR ○ ☐ STEAM. PRESSURE ______ psig
☐ STM. FLOW ______ LBS/HR.
○ VACUUM PUMP (15.6.2), SEE SPEC. ______
○ CONDENSATE RECEIVER
○ LOOP SEAL HEIGHT ______ ft

INSPECTION AND TESTING (16.2) (16.3)

GENERAL

○ SHOP INSPECTION (16.1.4)
EXTENT: ______
○ REFERENCE INSPECTION CHECKLIST "I"

INSPECTION AND MATERIAL TESTING

○ FINAL ASSEMBLY RECORDS REQUIRED (16.2.1.1.f)
SPECIAL MATERIAL INSPECTION & TESTING REQUIREMENTS

COMPONENT	MAG PART	DYE PEN	R.T.	U.T.	OBSVD	WIT
TRIP & T & T VALVE	○	○	○	○	○	○
STM CHEST	○	○	○	○	○	○
CASING	○	○	○	○	○	○
PIPING	○	○	○	○	○	○
ROTOR	○	○	○	○	○	○
					○	○

	OBSVD	WIT
○ HEAT STABILITY (16.2.2)	○	○
○ CLEANLINESS (16.2.3.3)	○	○
○ HARDNESS (16.2.3.4)	○	○
○ HYDRO TESTS (16.3.2)	○	○
○ BLADE SHAKER (STATIC)	○	○
ROTOR BALANCE ○ STANDARD (9.6.1)(9.6.2)	○	○
○ HIGH SPEED (9.6.3)	○	○
○ LOW SPEED PRIOR TO HIGH SPEED(9.6.6)	○	○
○ LOW SPEED RESIDUAL UNBALANCE CHECK(9.6.7)	○	○
○ FINAL SURFACE INSPECTION (16.4.3)	○	○
○ CRATING INSPECTION (16.4.1)	○	○
○ SPARE ROTOR FIT	○	○
○ CASING JOINT LEAK TEST (16.3.2.3)	○	○
○ ______	○	○

MECHANICAL RUNNING TEST (16.3.3)

	OBSVD	WIT
○ CONTRACT ROTOR	○	○
○ SPARE ROTOR	○	○
○ TEST W/JOB COUPLING	○	○
○ TEST TAPE RECORD REQUIRED	○	○
○ TEST TAPE GIVEN TO PURCH.	○	○
○ POLAR PLOTS REQUIRED	○	○
○ TEST W/JOB LUBE OIL CONSOLE	○	○

OPTIONAL TESTS (16.3.4)

	OBSVD	WIT
○ PERFORMANCE (16.3.4.2)	○	○
○ COMPLETE UNIT (16.3.4.3)	○	○
	○	○
AUXILIARY EQUIPMENT (16.3.4.4)		
○ TRIP/TRIP & THROTTLE VALVE	○	○
○ GLAND SEAL SYSTEM	○	○
○ GLAND VACUUM SYSTEM	○	○
○ RELIEF VALVES	○	○
○ ______	○	○
○ CASING INTERNAL INSP (16.3.4.5)	○	○
○ COUPLING TO SHAFT FIT (ISO 10441)	○	○
○ TURNING GEAR	○	○
○ OVERSPEED SHUTDOWN SYSTEM	○	○
○ GOVERNOR RESPONSE (16.3.4.10)	○	○
○ SOUND (16.3.4.11)	○	○
○ SPARE PARTS TESTS (16.3.4.7)	○	○
○ ______	○	○
○ ______	○	○

SPECIAL-PURPOSE STEAM TURBINE DATA SHEET US CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 10 OF 10 BY ______

MISCELLANEOUS

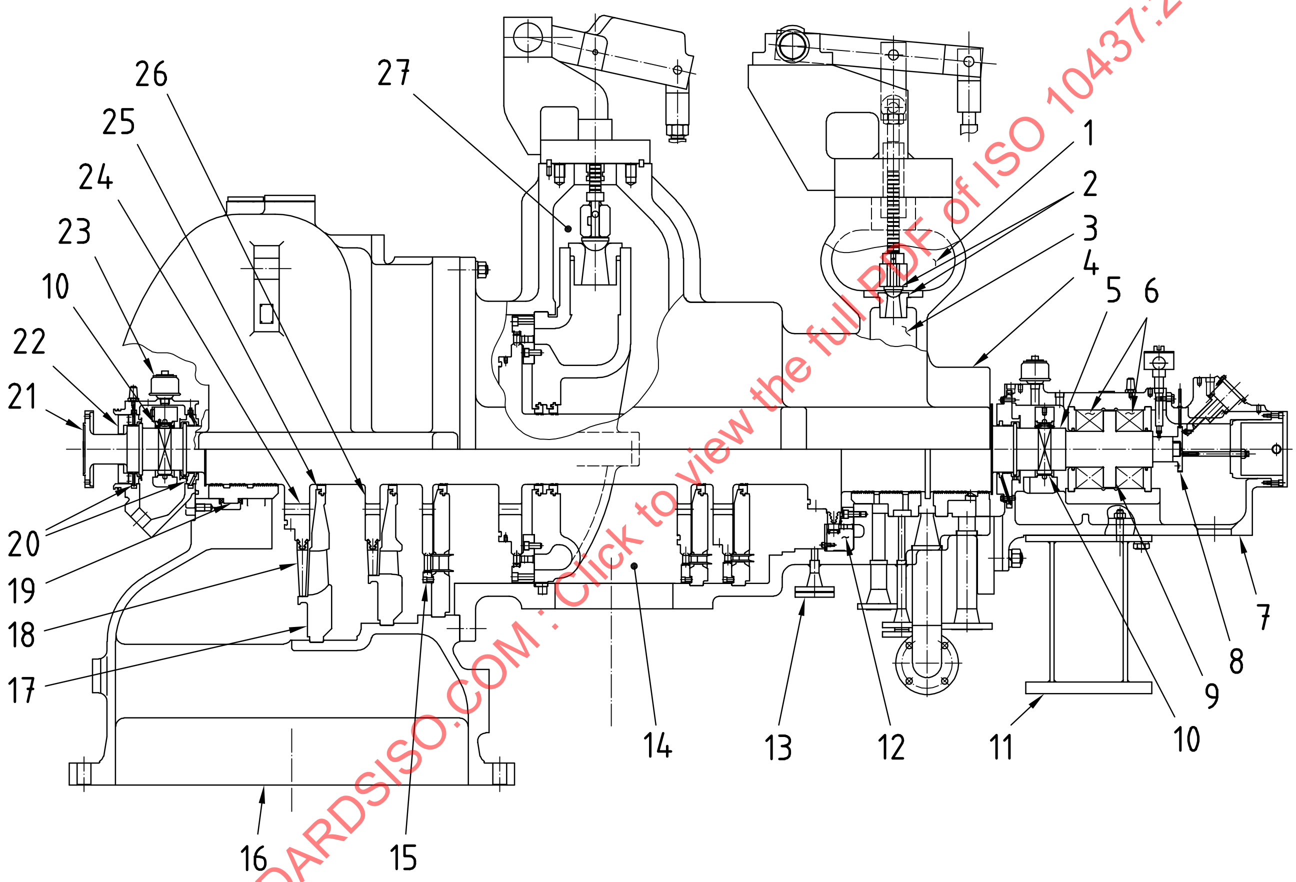
PAINTING ○ MANUFACTURER'S STANDARD ○ OTHER ______	**WEIGHTS:** ☐ TURBINE ______ lb ☐ ROTOR ______ lb ☐ TURBINE UPPER HALF CASING ______ lb
UNIT NAMEPLATE UNITS ○ U.S. CUSTOMARY ○ SI	☐ MAXIMUM FOR MAINTENANCE (IDENTIFY) ______ lb
SHIPMENT (16.4.1) (16.4.3.j) ○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQD. ○ OUTDOOR STORAGE OVER 6 MONTHS ○ WATERPROOF BOXING REQUIRED ○ SPARE ROTOR ASSEMBLY PACKAGED FOR: ○ HORIZONTAL STORAGE ○ VERTICAL STORAGE	☐ TRIP / TRIP & THROTTLE VALVE ______ lb ☐ MISCELLANEOUS ______ lb ☐ TOTAL SHIPPING MASS ______ lb
SPACE REQUIREMENTS: ☐ COMPLETE UNIT: L ______ in W ______ in H ______ in ☐ CONTROL PANEL: L ______ in W ______ in H ______ in ☐ OTHER: L ______ in W ______ in H ______ in ☐ OTHER: L ______ in W ______ in H ______ in	**VENDOR DRAWING & DATA REQUIREMENTS (17)** ○ ANNEX J ○ OTHER ______

REMARKS AND ADDITIONAL REQUIREMENTS:

Annex B
(informative)

Steam turbine nomenclature

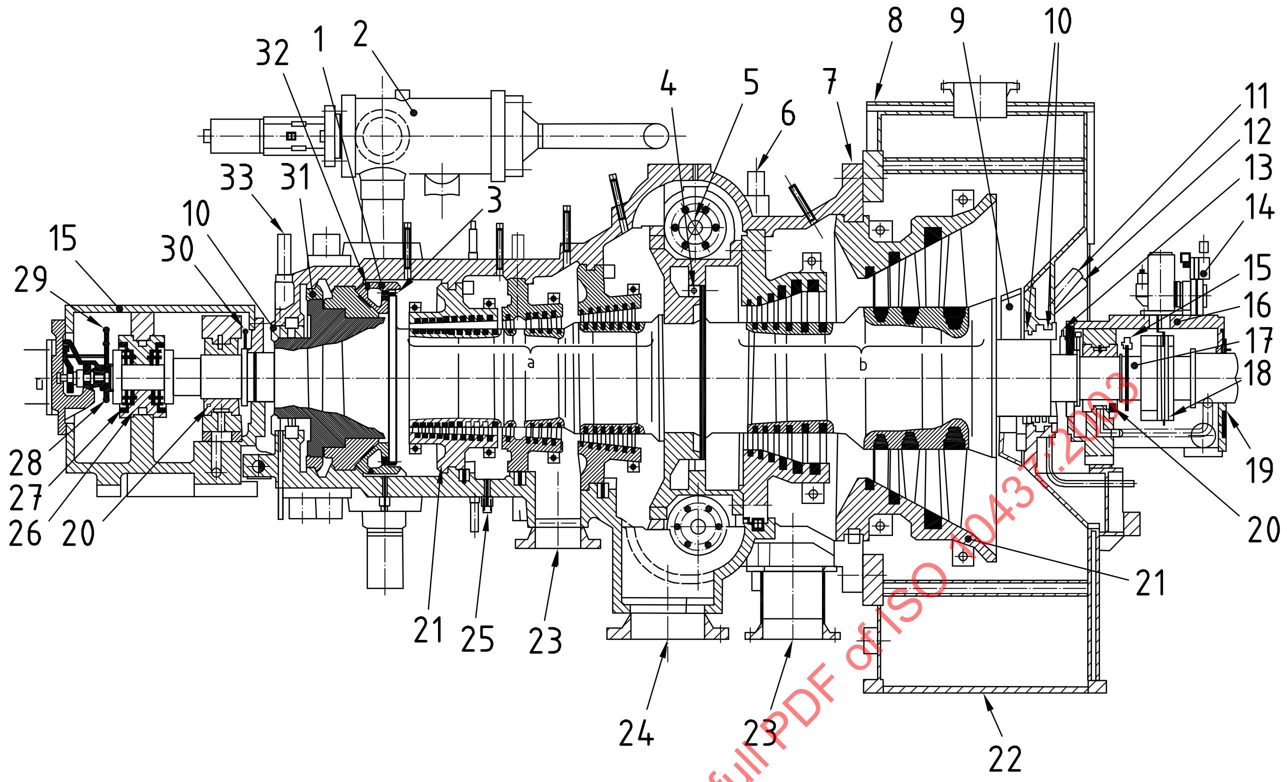
Figures B.1 and B.2 are included only to clarify the nomenclature for standard machine parts and are in no way intended to show preferred design solutions or establish any design requirements whatsoever. The machine parts depicted here might not all be present in each turbine or might have a different 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 International Standard.



Key

1 steam chest
2 inlet valves and seats
3 nozzle chamber
4 casing
5 rotor shaft sensing area
6 thrust bearings
7 bearing housing
8 multi-toothed speed sensing surface
9 thrust collar
10 journal bearing
11 support
12 control stage nozzle ring
13 casing drain
14 controlled extraction/injection nozzle
15 tip seal
16 exhaust connection
17 diaphragm
18 rotor blades
19 shaft outer seals
20 bearing housing end seals
21 rotor
22 bearing housing deflector
23 breather/vent
24 steam balance hole
25 interstage seals
26 wheel (disk)
27 LP section control valves

Figure B.1 — Typical impulse steam turbine nomenclature



a HP Reaction staging.

b HR Reaction staging.

Key

1 HP nozzle element
2 inlet control valves
3 control stage impulse blading
4 LP nozzles inner casing
5 LP 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 HP nozzles inner casing
33 balance line

Figure B.2 — Typical reaction steam turbine nomenclature

Annex C
(normative)

Procedures for determining residual unbalance

C.1 Scope

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

C.2 Terms and definitions

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

C.2.1
residual unbalance
amount of unbalance remaining in a rotor after balancing

NOTE Unless otherwise specified, residual unbalance is expressed in g·mm (oz-in).

C.3 Maximum allowable residual unbalance

C.3.1 The maximum allowable residual unbalance per plane shall be calculated in accordance with 9.6.2, using Equation (6).

C.3.2 If the actual static load on each journal is not known, it shall be assumed that the total rotor mass is equally supported by the bearings.

EXAMPLE A two-bearing rotor with a mass of 2 700 kg (6 000 lb) would be assumed to impose a mass of 1 350 kg (3 000 lb) on each journal.

C.4 Residual unbalance check

C.4.1 General

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

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

C.4.2 Procedure

C.4.2.1 Select a trial mass and radius that is equivalent to between one and two times the maximum allowable residual unbalance [i.e., if U_{max} is 1 440 g·mm (2 oz-in), the trial mass should cause 1 440 g·mm to 2 880 g·mm (2 oz-in to 4 oz-in) of unbalance].

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

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

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

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

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

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

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

Equipment (rotor) No.: ____________

Purchase order No.: ____________

Correction plane (inlet, drive end, etc. — use sketch):

Balancing speed: ____________ r/min

n = maximum allowable rotor speed: ____________ r/min

m = mass of journal (closest to this correction plane): ____________ kg/lb

U_{max} = maximum allowable residual unbalance =

6 350 m/n (4 m/n)

6 350 × ______ kg/ ______ r/min; (4 min × ______ lb/ ______ r/min) ______ g·mm (oz-in)

Trial unbalance (2 × U_{max}) ____________ g·mm (oz-in)

R = radius (at which mass shall be placed): ____________ mm (in)

Trial unbalance mass = Trial unbalance/R

______ g·mm/______ (______ oz-in/ ______ in) ______ g (oz)

Conversion Information: 1 ounce = 28,350 grams

Test data **Rotor sketch**

Position	**Trial mass** **Angular location**	**Balancing machine** **Amplitude readout**
1	0°	
2	60°	
3	120°	
4	180°	
5	240°	
6	300°	
Repeat 1	0°	

Test Data — Graphic Analysis

Step 1: Plot data on the polar chart (Figure C.1 continued). Scale the chart so the largest and smallest amplitudes fit conveniently.

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

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

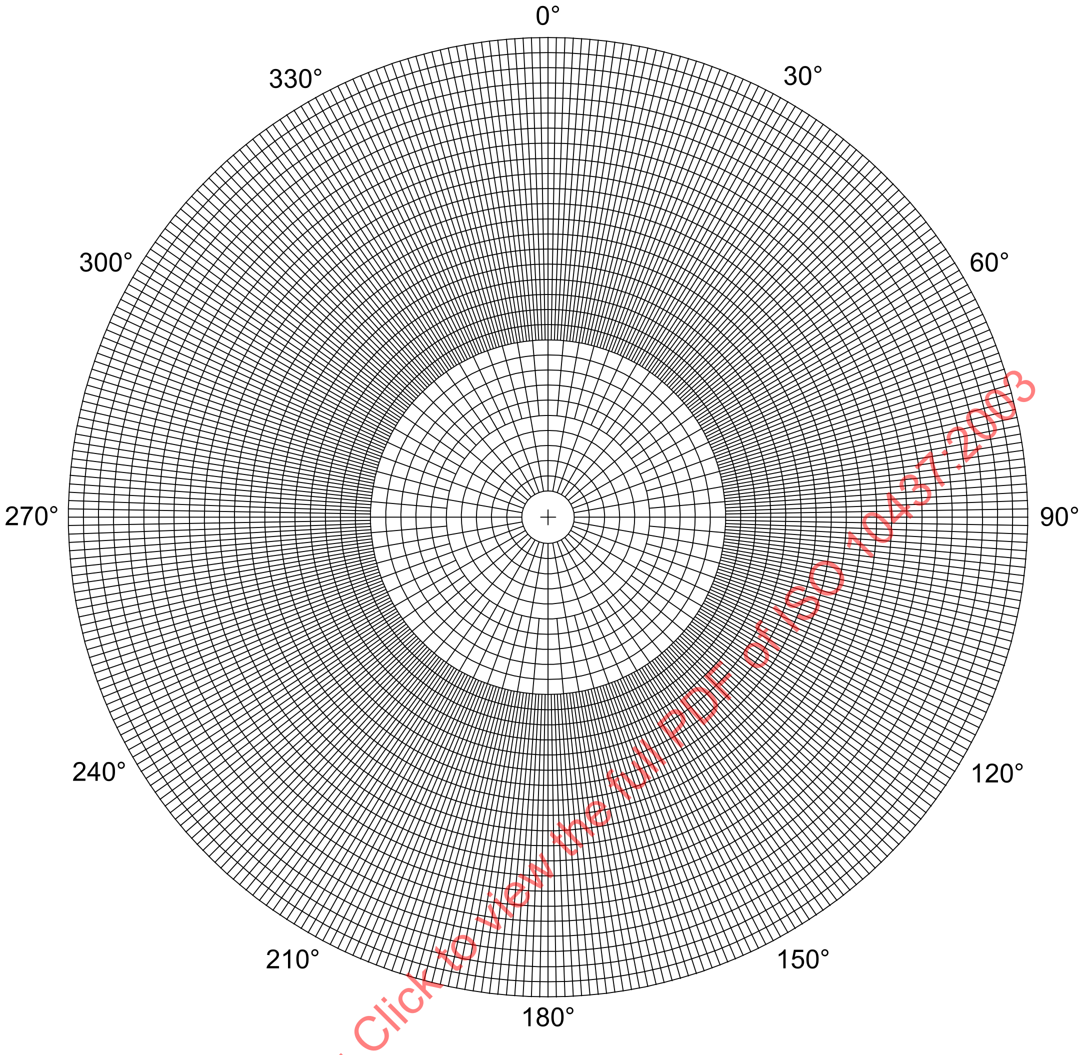
Step 4: Record the trial unbalance from above. ____________ g·mm (oz-in)

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

Step 6: Divide the answer in Step 5 by the answer in Step 3. ____________ Scale factor

A correlation has now been made between the units on the polar chart and the actual balance.

Figure C.1 — Residual unbalance work sheet



The circle drawn shall contain the origin of the polar chart. If it doesn’t, the residual unbalance of the rotor exceeds the applied test unbalance.

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

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

Record actual residual unbalance ________________ (g·mm)(oz-in)

Record allowable residual unbalance (from Figure C.1) ________________ (g·mm)(oz-in)

Correction plane ________________ for rotor No. ___________________ (has/has not) passed

By ____________________________ Date _________________________

Figure C.1 — Residual unbalance worksheet *(continued)*

Equipment (rotor) No.: C-101

Purchase order No.: ____________

Correction plane (inlet, drive end, etc.—use sketch): A

Balancing speed: 800 r/min

n = maximum allowable rotor speed: 10 000 r/min

m = mass of journal (closest to this correction plane): 908 ~~kg~~ lb

U_{max} = maximum allowable residual unbalance =

6 350 m/n (4 m/n)

~~6350 × ________ kg/________ r/min~~; (4 × 908 lb/10 000 r/min) 0,36 ~~g·mm~~(oz-in)

Trial unbalance (2 × U_{max}) 0,72 ~~g·mm~~ (oz-in)

R = radius (at which mass shall be placed): 6,875 ~~mm~~ (in)

Trial unbalance mass = Trial unbalance/R ____________

~~______ g·mm/______ mm~~ 0,72 oz-in/ 6,875 in 0,10 ~~g~~ (oz)

Conversion Information: 1 ounce = 28,350 grams

Test data **Rotor sketch**

Position	**Trial mass Angular location**	**Balancing machine Amplitude readout**
1	0°	14,0
2	60°	12,0
3	120°	14,0
4	180°	23,5
5	240°	23,0
6	300°	15,5
Repeat 1	0°	13,5

Test Data — Graphic Analysis

Step 1: Plot data on the polar chart (Figure C.2 continued). Scale the chart so the largest and smallest amplitudes fit conveniently.

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

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record. 35 units

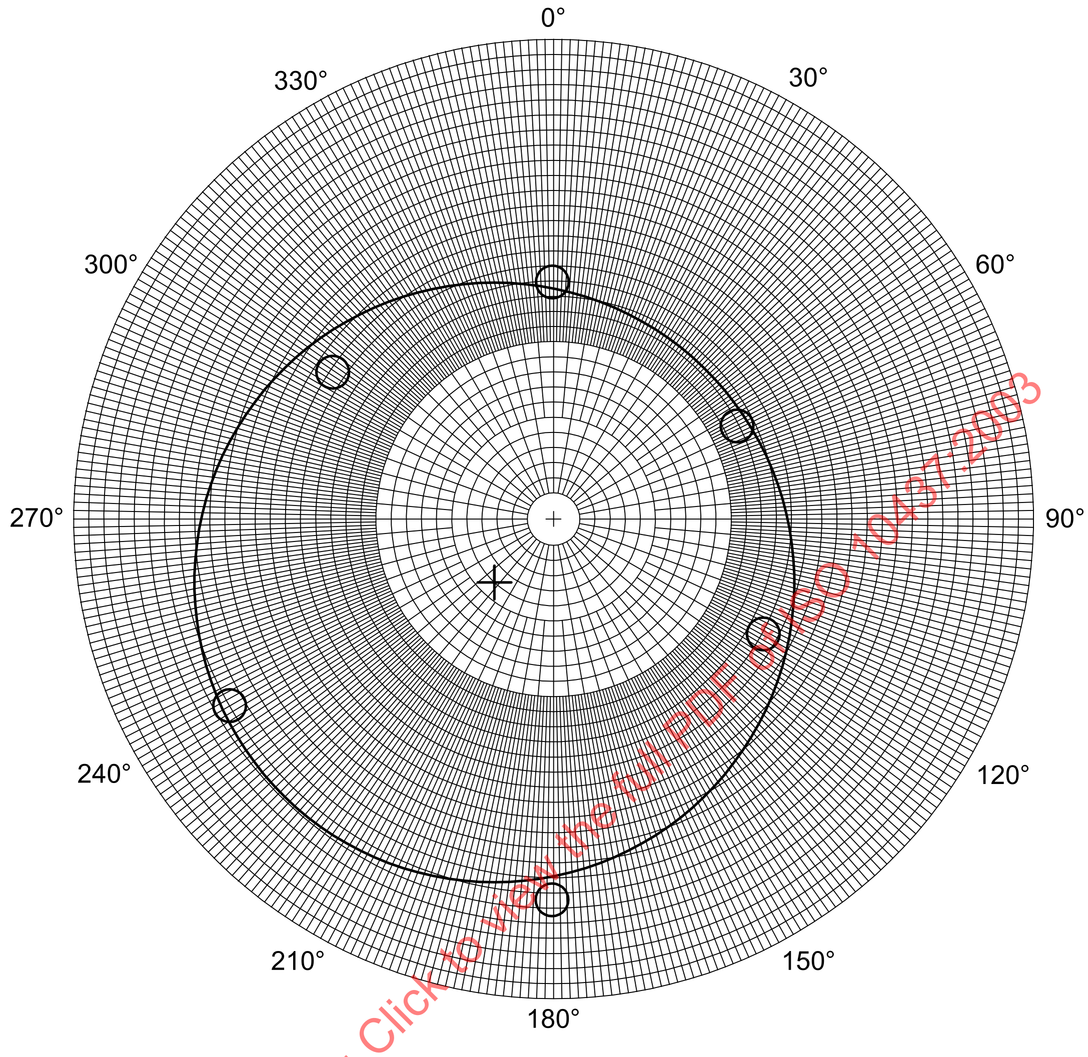
Step 4: Record the trial unbalance from above. 0,72 ~~g·mm~~ (oz-in)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). 1,44 ~~g·mm~~ (oz-in)

Step 6: Divide the answer in Step 5 by the answer in Step 3. 0,041 Scale factor

A correlation has now been made between the units on the polar chart and the actual balance.

Figure C.2 — Sample calculations for residual unbalance



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

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

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

Record actual residual unbalance 5 (0,041) = 0,21 (~~g·mm~~)(oz-in)

Record allowable residual unbalance (from Figure C.1) 0,36 (~~g·mm~~)(oz-in)

Correction plane A for rotor No. C-101 (has/~~has not~~) passed.

By John Inspector Date 11-31-94

Figure C.2 — Sample calculations for residual unbalance *(continued)*

Annex D
(informative)

Alarm and shutdown systems

NOTE The requirements of 12.4.7 a) to 12.4.7 c), and 12.4.9 b) may be satisfied in many ways. For the guidance of the purchasers and vendors, three possible arrangements which satisfy these requirements are described below.

D.1 Arrangement 1

D.1.1 Alarms and shutdowns are initiated by conventional, locally mounted, direct-acting switches.

D.1.2 Alarms and shutdown switches are completely independent of each other.

D.1.3 Each alarm and shutdown switch is furnished in a separate housing, located to facilitate inspection and maintenance. Switch settings are not adjustable from outside the housing.

D.1.4 Alarm switches and, if specified, shutdown switches are connected through normally energized, fail-safe circuits. The shutdown circuit wiring is completely independent from the alarm circuit wiring and is run in a separate conduit or armoured cable.

D.1.5 The necessary switches, links and other features are provided to enable the system to be tested. Warning devices are incorporated to indicate when any part of the system is disarmed.

D.2 Arrangement 2

D.2.1 Shutdowns are initiated by local, direct-acting switches connected as described in Arrangement 1 (see D.1).

D.2.2 Alarms operate through locally mounted transmitters (electronic or pneumatic) connected to either separate panel mounted switches or to a multi-point scanning type instrument.

D.2.3 Where a multi-point scanning type instrument is used, the alarm setting for each parameter is separately and independently adjustable.

D.2.4 As in Arrangement 1, the necessary switches, links, and other features, together with the associated warning devices, are provided to enable the system to be tested.

D.3 Arrangement 3

D.3.1 For each parameter for which both an alarm and a shutdown is specified, three separate and independent electronic transmitters are provided.

D.3.2 Each transmitter associated with each measured parameter is independently connected to a different one of three multi-point, electronic scanning type instruments. Connections are made through separate cables.

D.3.3 Each multi-point instrument provides both an alarm and shutdown output, separately and independently adjustable for each transmitted output.

D.3.4 The shutdown and alarm function outputs from the three multi-point instruments are connected through a suitable voting logic system. The system is such that operation of any one alarm or shutdown function shall initiate an alarm; operation of two shutdown functions monitoring the same parameter shall initiate a separate alarm and cause the equipment to shut down. If specified, the voting logic system is duplicated or otherwise provided with suitable redundancy.

D.3.5 Alarm functions which are not associated with a shutdown function, are each provided with one single transmitter. These alarm transmitters may be connected to one of the three multi-point alarm/shutdown instruments or to a separate multi-point instrument.

D.3.6 Features that enable each transmitter to be tested are provided but disarming switches or links are not required.

NOTE Arrangement 3 has the following advantages:

— any shutdown or alarm function can be tested at any time with equipment in service and without the need to disarm any part of the system;

— failure of any one component shall initiate an alarm but shall not result in equipment shutdown;

— the use of modern digital instrument technology is facilitated.