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

API STANDARD 611
FOURTH EDITION, JUNE 1997

American
Petroleum
Institute

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Manufacturing, Distribution and Marketing Department

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FOREWORD

This standard is based on the accumulated knowledge and experience of manufacturers and users of steam turbines. The objective of this publication is to provide a purchase specification to facilitate the manufacture and procurement of general-purpose steam turbines for use in petroleum refinery service.

The primary purpose of API standards for mechanical equipment is to establish minimum mechanical requirements. This limitation in scope is one of charter as opposed to interest and concern. Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy-conserving approaches should be aggressively pursued by the manufacturer and user during these steps. Alternative approaches that may result in improved energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, since the evaluation of purchase options will be based increasingly on total life costs as opposed to acquisition cost alone. Equipment manufacturers, in particular, are encouraged to suggest alternatives to those specified when such approaches achieve improved energy effectiveness and reduce total life costs without sacrifice of safety or reliability.

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

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IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of great usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the proposed rule by the U.S. Environmental Protection Agency (EPS) proposing labeling requirements and phased banning of asbestos products, published at 51 *Federal Register* 3738-3759 (January 29, 1986; the most recent edition should be consulted).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials which can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

CONTENTS

Page

Figures

Tables

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

1 Scope

1.1 PURPOSE

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

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

1.1.1 Steam turbines are classified general-purpose or special-purpose according to service requirements as described in 1.1.1.1 and 1.1.1.2.

1.1.1.1 General-purpose turbines are horizontal or vertical turbines used to drive equipment that is usually spared, is relatively small in size (power), or is in non-critical service. They are generally used where steam conditions will not exceed a pressure of 48 bar (700 pounds per square inch gauge) and a temperature of 400°C (750°F) or where speed will not exceed 6000 revolutions per minute.

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

1.2 ALTERNATIVE DESIGNS

The vendor may offer alternative designs. Equivalent metric dimensions, fasteners, and flanges may be substituted as mutually agreed upon by the purchaser and the vendor.

1.3 CONFLICTING REQUIREMENTS

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

2 References

2.1 REFERENCED PUBLICATIONS

2.1.1 Referenced international standards are included in Appendix G. The editions that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the purchaser and the vendor.

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

2.1.3 It is the vendor's responsibility to invoke all applicable specifications to each subvendor.

3 Definitions

Terms used in this standard are defined in 3.1 through 3.30.

3.1 axially split: Casing joints that are parallel to the shaft centerline.

3.2 circulating oil system: Withdraws oil from the housing of bearings equipped with oil rings and cools it in an external oil cooler before it is returned to the bearing housing.

3.3 design: The use of the word design in any term (such as design power, design pressure, design temperature, or design speed) should be avoided in the purchaser's specifications. This terminology should be used only by the equipment designer and the manufacturer.

3.4 gauge board: Unenclosed bracket or plate used to support and display gauges, switches, and other instruments.

3.5 hydrodynamic bearings: Bearings that use the principles of hydrodynamic lubrication. Their surfaces are oriented so that relative motion forms an oil wedge to support the load without journal-to-bearing contact.

3.6 local: A device mounted on or near the equipment or console.

3.7 maximum allowable speed (in revolutions per minute): The highest speed at which the manufacturer's design will permit continuous operation.

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

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

3.10 maximum continuous speed (in revolutions per minute): The speed at least equal to 105 percent of the highest speed required by any of the specified operating conditions.

3.11 maximum exhaust casing pressure: The highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions.

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

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

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

3.14 minimum allowable speed (in revolutions per minute): The lowest speed at which the manufacturer's design will permit continuous operation.

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

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

3.17 NEMA inlet and exhaust conditions: Equivalent to the maximum inlet and exhaust steam conditions specified on the data sheets.

3.18 normal: Applies to the power, speed, and steam conditions at which the equipment will usually operate. These conditions are the ones at which the highest efficiency is desired.

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

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

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

3.22 pure oil mist lubrication (dry sump): The mist both lubricates the bearing and purges the housing.

3.23 purge oil mist lubrication (wet sump): The mist only purges the bearing housing. Bearing lubrication is by conventional oil bath, flinger, or oil ring.

3.24 radially split: Casing joints that are transverse to the shaft centerline.

3.25 rated: The greatest turbine power specified and the corresponding speed. It includes all of the margin required by the driven-equipment specifications.

3.26 standby service: A normally idle or idling piece of equipment that is capable of immediate automatic or manual start-up and continuous operation.

3.27 total indicated runout (TIR): Also known as total indicator reading, is the runout of a diameter or face determined by measurement with a dial indicator. The indicator reading implies an out-of-squareness equal to the reading or an eccentricity equal to half the reading.

3.28 trip speed (in revolutions per minute): The speed at which the independent emergency overspeed device operates to shut down the turbine. The trip speed setting will vary with the class of governor.

3.29 unit responsibility: The responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order. It includes responsibility for reviewing such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, and testing of components.

3.30 vendor: The agency that manufactures, sells, and provides service support for the equipment.

4 Basic Design

4.1 GENERAL

4.1.1 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. It is recognized that this is a design criterion.

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

4.1.3 The equipment's normal operating point will be specified on the data sheets.

4.1.4 Turbines shall be capable of the following:

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

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

Note: Rated power may be achieved by using a hand valve or valves under normal steam conditions and an additional hand valve or valves under minimum inlet and maximum exhaust steam conditions. See 5.4.1.5 for information about using hand valves at other operating conditions.

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

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

e. Operating with variations from rated steam conditions in accordance with NEMA SM 23.

Note: Regardless of the design limit of any turbine component, the turbine should not be operated or rerated outside the nameplate limits without consultation with the manufacturer.

4.1.5 Equipment shall be designed to run to the trip speed and relief valve settings without damage.

4.1.6 Single-stage turbines shall be suitable for immediate start-up to full load without a preliminary warm-up period. The purchaser will allow for proper drainage of the inlet piping, turbine casing, steam chest, and packing glands.

Note: Consultation with the manufacturer is recommended, since additional considerations may be required when single-stage turbines are to be applied for immediate automatic unattended start-up.

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

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

4.1.9 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or cylindrically doweled) and manufactured to ensure accurate alignment on reassembly.

4.1.10 The turbine and other equipment within the scope of the order shall perform on the test stand and 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.

4.1.11 Unless otherwise specified, cooling water systems shall be designed in accordance with 4.1.11.1 and 4.1.11.2.

4.1.11.1 A cooling water system or systems shall be designed for the following conditions:

Velocity over heat exchanger surfaces	1.5-2.5 m/s	5-8 ft/s
Maximum allowable working pressure	≥6.9 bar	≥100 psig
Test pressure	≥10.4 bar	≥150 psig
Maximum pressure drop	1 bar	15psi
Maximum inlet temperature (see note)	30°C	90°F
Maximum outlet temperature	50°C	120°F
Maximum temperature rise	20°K	30°F
Minimum temperature rise	10°K	20°F
Fouling factor on water side	0.35 m^2K/kW	0.002 $hr\text{-}ft^2\text{-}°F/Btu$
Shell corrosion allowance	3.0mm	0.125 in.

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

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

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

● **4.1.12** 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 by the purchaser.

● **4.1.13** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser on the data sheets and shall meet the requirements of NFPA 70, Articles 500, 501, 502, and 504, as well as local codes specified and furnished by the purchaser.

● **4.1.14** The purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions).

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

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

4.2 PRESSURE CASINGS

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

4.2.2 The hoop-stress values used in the design of the casing shall not exceed the maximum allowable stress values in tension specified in Section VIII, Division 1, of the ASME Code at the maximum operating temperature of the material used.

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

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

4.2.5 Radially split horizontal turbines shall be designed to permit inspection and replacement of the bearings and outer glands without removing the casing from its foundation or disconnecting inlet or exhaust steam piping.

Note: Radially split horizontal turbines may require removal from their foundations to permit removal of rotors.

4.2.6 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change of shaft alignment at the coupling flange (caused by the worst combination of allowable pressure, torque, and piping forces and moments) to 50 micrometers (0.002 inch). Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of lateral and axial jackscrews. Axially split horizontal turbines shall have centerline supports to maintain proper alignment with connected equipment. The lower horizontal mounting surface of each turbine support shall be machined parallel within 0.17 millimeter per meter (0.002 inch per foot) (1:6000). Corresponding surfaces shall be coplanar within 0.17 millimeter per meter of distance between surfaces (0.002 inch per foot).

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

● **4.2.7.1** On condensing turbines, when required by the orientation of the exhaust nozzle or piping, or when specified by the purchaser, the vendor shall provide an automatic draining system with the turbine.

4.2.8 Gauge connections shall be provided for the steam-ring chamber on single-valve turbines and for the first stage of multistage turbines.

4.2.9 Jackscrews, guide rods (for multistage turbines), and cylindrical casing alignment dowels shall be provided to facilitate disassembly and reassembly. When jackscrews are used to part contacting faces, one of the faces shall be relieved (counterbored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face. 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. Methods of lifting the assembled machine shall be specified by the vendor.

4.2.10 The use of tapped holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and tapped holes. The depth of the tapped holes shall be at least $1^1/_2$ times the stud diameter.

4.2.11 Bolting shall be furnished as specified in 4.2.11.1 through 4.2.11.5.

4.2.11.1 The details of threading shall conform to ASME B1.1.

4.2.11.2 Studs are preferred to cap screws.

4.2.11.3 Studded connections shall be furnished with studs and nuts installed. Blind stud holes should be drilled only deep enough to allow a preferred tap depth of $1^1/_2$ times the major diameter of the stud; the first $1^1/_2$ threads at both ends of each stud shall be removed.

4.2.11.4 Slotted-nut or spanner-type bolting shall not be used unless specifically approved by the purchaser.

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

4.2.12 The machined finish of the mounting surface shall be 3 to 6 micrometers (125 to 250 microinches) arithmetic average roughness (R_a). Hold-down or foundation bolt holes shall be drilled perpendicular to the mounting surface or surfaces and spot faced to a diameter three times that of the hole.

● **4.2.13** When specified, the equipment feet shall be equipped with vertical jackscrews.

4.2.14 Equipment feet shall be drilled with pilot holes for use in final doweling.

4.3 CASING APPURTENANCES

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

4.4 CASING CONNECTIONS

● **4.4.1** Inlet and outlet connections shall be flanged or machined and studded, oriented as specified on the data sheets, and suitable for the maximum inlet and maximum exhaust steam conditions as specified and defined in 3.1.12 and 3.1.13.

4.4.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping. All welding of connections shall be done before hydrostatic testing.

4.4.3 Casing openings for piping connections shall be at least NPS $^3/_4$ and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes NPS $^3/_4$ through $1^1/_2$ are permissible. These threaded openings shall be installed as specified in 4.4.3.1 through 4.4.3.7.

4.4.3.1 A pipe nipple, preferably not more than 150 millimeters (6 inches) long, shall be screwed into the threaded opening.

4.4.3.2 Pipe nipples shall be a minimum of Schedule 160 seamless for sizes NPS 1 and smaller and a minimum of Schedule 80 seamless for sizes NPS $1^1/_2$ and larger.

4.4.3.3 Pipe nipples shall be provided with welding-neck or socket-weld flanges for steam pressures of 12 bar (175 psig) or higher.

4.4.3.4 Threaded connections shall be seal welded; however, seal welding is not permitted on cast iron equipment, for instrument connections, or where disassembly is required for maintenance. Seal-welded joints shall be in accordance with ASME B31.3.

4.4.3.5 Tapped openings and bosses for pipe threads shall conform to ASME B16.5.

4.4.3.6 Pipe threads shall be taper threads that conform to ASME B1.20.1.

4.4.3.7 Openings for socket-welded connections shall conform to ASME B16.11.

4.4.4 Openings for NPS $1^1/_4$, $2^1/_2$, $3^1/_2$, 5, 7, and 9 shall not be used.

4.4.5 Tapped openings not connected to piping shall be plugged with solid round-head steel plugs furnished in accordance with ASME B16.11. As a minimum, these plugs shall meet the material requirements of the casing. Plugs that may later require removal shall be of corrosion-resistant material. A lubricant that meets the proper temperature specification shall be used on all threaded connections. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.

4.4.6 Flanges shall conform to ASME B16.1 or B16.5, or B16.42 as applicable, except as specified in 4.4.6.1 through 4.4.6.5.

4.4.6.1 Cast iron flanges shall be flat faced and shall have a minimum thickness of Class 250 in accordance with ASME B16.1 for sizes 8 inches and smaller.

4.4.6.2 Flat-faced flanges are acceptable on all exhaust connections. Flat-faced flanges shall have full raised-face thickness.

4.4.6.3 Flanges that are thicker or have a larger outside diameter than that required by ASME B16.1, B16.5, or B16.42, as applicable, are acceptable.

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

● **4.4.6.5** For the purpose of manufacturing mating parts, the vendor shall supply equipment flange details to the purchaser when connections larger than those covered by ASME B16.5 or B16.42 are supplied. When specified, the mating parts shall be furnished by the vendor.

4.4.7 The finish of the contact faces of flanges and nozzles shall conform to the flange-finish roughness requirements in Table 1. Milled flanged surfaces are acceptable with the purchaser's approval.

Table 1—Arithmetic Average Roughness Height (R_a)

Type	Service	Contact Surface Roughness (R_a) Microinches
Flat and raised face	Vacuum	63-125
	Above atmospheric	125-500
Ring joint	All	<63

4.4.8 All of the purchaser's connections shall be accessible for disassembly without moving the machine.

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

4.5 EXTERNAL FORCES AND MOMENTS

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

4.6 ROTATING ELEMENTS

4.6.1 Rotors

4.6.1.1 Rotors shall be capable of operating without damage at momentary speeds up to 110 percent of trip.

4.6.1.2 Rotors (other than integrally forged shafts and disks) shall be assembled to prevent movement of the disk relative to the shaft when operating at any specified start-up or operating condition and any speed up to 110 percent of trip speed. The wheels shall be keyed to the shaft and assembled with a shrink fit.

The purchaser's specific approval is required for built-up rotors when blade tip velocities at maximum continuous speed exceed 250 meters per second (825 feet per second) or when stage inlet steam temperatures exceed 440°C (825°F).

4.6.2 Shafts

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

When noncontacting vibration and/or axial position probes are furnished or provisions for them are specified, the rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 0.8 micrometer (32 microinches R_a, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API Standard 670 or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 percent of the maximum allowed peak-to-peak vibration amplitude or the following value, whichever is greater:

a. For areas to be observed by radial vibration probes, 5 micrometers (0.25 mil). Add shaft burnishing automatically whenever provisions for vibration probes are specified.

b. For areas to be observed by axial-position probes, 10 micrometers (0.5 mil).

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

4.6.2.2 Keyways shall have fillet radii conforming to ASME B17.1.

4.6.3 Blading

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

4.6.3.2 All blades shall be mechanically suitable for operation (including transient conditions) over the specified speed range and momentarily up to 110 percent of trip speed.

4.7 SEALS

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

4.7.2 Carbon-ring packing shall be used only when the rubbing speed at the shaft sealing surface is less than 50 meters per second (160 feet per second). The number of carbon rings shall be determined by the service and venting requirements, with 2.4 bar (35 pounds per square inch) being the maximum allowable average differential pressure per active sealing ring. Springs for carbon packing shall be made of nickel-chromium-iron alloy (heat treated after cold coiling) or equal material. Variations in operating steam temperature shall be considered when the required cold clearances for packing rings are established.

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

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

● **4.7.5** Glands that operate at less than atmospheric pressure shall be designed to admit steam that will seal against air leakage. Piping with relief valves, pressure gauges, regulators. and other necessary valves shall be provided to interconnect the end glands. Piping shall have one common connection to the purchaser's sealing-steam supply. When specified, the admission of sealing steam shall be automatically controlled throughout the load range. The normal operating sealing-steam supply shall preferably come from a positive-pressure section of the turbine.

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

4.7.7 Sealing of interstage diaphragms on multistage turbines shall be by replaceable labyrinth packing.

4.7.8 The gland casing leakoff connections shall comply with 4.4.3.

4.8 DYNAMICS

4.8.1 Critical Speeds

4.8.1.1 When the frequency of a periodic forcing phenomenon (exciting frequency) applied to a rotor-bearing support system corresponds to a natural frequency of that system, the system may be in a state of resonance.

4.8.1.2 A rotor-bearing support system in resonance will have its normal vibration displacement amplified. The magnitude of amplification and the rate of phase-angle change are related to the amount of damping in the system and to the mode shape taken by the rotor.

Note: The mode shapes are commonly referred to as the first rigid (translatory or bouncing) mode, the second rigid (conical or rocking) mode, and the (first, second, third, . . ., nth) bending mode.

4.8.1.3 When the rotor amplification factor (see Figure 1), as measured at the shaft radial vibration probes, is greater than or equal to 2.5, that corresponding frequency is called a critical speed, and the corresponding shaft rotational frequency is also called a *critical speed*. For the purposes of this standard, a critically damped system is one in which the amplification factor is less than 2.5.

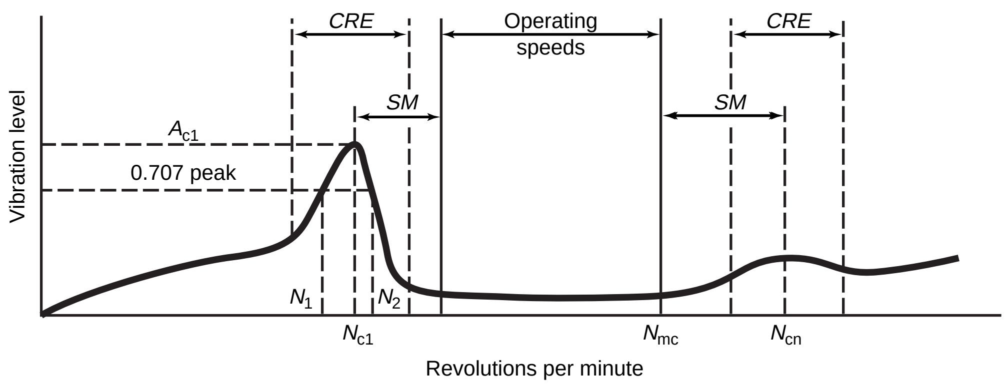
4.8.1.4 An exciting frequency may be less than, equal to, or greater than the rotational speed of the rotor. Potential exciting frequencies that are considered in system design shall include but are not limited to the following sources:

a. Unbalance in the rotor system.
b. Oil-film instabilities (whirl).
c. Internal rubs.
d. Blade, vane, nozzle, and diffuser passing frequencies.
e. Gear-tooth meshing and side bands.
f. Coupling misalignment.
g. Loose rotor-system components.
h. Hysteretic and friction whirl.
i. Boundary-layer flow separation.
j. Acoustic and aerodynamic cross-coupling forces.
k. Asynchronous whirl.
l. Ball and race frequencies of antifriction bearings.

4.8.1.5 Resonances of structural support systems may adversely affect the rotor vibration amplitude. Therefore, resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the specified separation margins (see B.1.4) unless the resonances are critically damped.

4.8.1.6 The vendor who is specified to have unit responsibility shall determine that the drive-train (turbine, gear, motor, and the like) critical speeds (rotor lateral, system torsional, blading modes, and the like) will not excite any critical speed of the machinery being supplied and that the entire train is suitable for the specified operating speed range, including any starting-speed detent (hold-point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for his review and included in the instruction manual for his guidance (see 7.3.6).

● **4.8.1.7** When specified, the turbine vendor shall supply all necessary information for lateral and torsional analyses to the vendor who has unit responsibility.



N_{c1} = Rotor first critical, center frequency, cycles per minute.
N_{cn} = Critical speed, nth.
N_{mc} = Maximum continuous speed, 105 percent.
N_1 = Initial (lesser) speed at 0.707 × peak amplitude (critical).
N_2 = Final (greater) speed at 0.707 × peak amplitude (critical).
$N_2 – N_1$ = Peak width at the half-power point.
AF = Amplification factor:
$= \frac{N_{c1}}{N_2 - N_1}$

SM = Separation margin.
CRE = Critical response envelope.
A_{c1} = Amplitude at N_{c1}.
A_{cn} = Amplitude at N_{cn}.

Figure 1—Rotor Response Plot

4.8.1.8 The first rigid mode of single-stage turbines shall be at least 120 percent of maximum continuous speed.

4.8.2 Lateral Analysis

4.8.2.1 The vendor's standard critical speed values that have previously been analytically derived and test proven for prior manufactured turbines of the same frame size and rotor/bearing configuration are acceptable and shall be submitted to the purchaser as part of the proposal. For new turbine designs and rotor/bearing configurations, the vendor shall perform a lateral critical analysis in accordance with the guidelines outlined in Appendix B.

● **4.8.2.2** When specified, the vendor shall provide calculations and/or available supporting test data for separation margins in accordance with 4.8.1.8 and B.1.4.

4.8.3 Torsional Analysis

4.8.3.1 Excitations of undamped torsional natural frequencies may come from many sources which should be considered in the analysis. These sources may include but are not limited to the following:

a. Gear problems such as unbalance and pitch line runout.
b. Start-up conditions such as speed detents and other torsional oscillations.
c. Hydraulic-governor control-loop resonances.
d. Running speed or speeds.

4.8.3.2 The vendor who has unit responsibility shall ensure that the undamped torsional natural frequencies of the complete train are at least 10 percent above or 10 percent below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

4.8.3.3 Torsional criticals at two or more times running speeds shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall be shown to have no adverse effect. In addition to multiples of running speeds, torsional excitations that are not a function of operating speeds or that are nonsynchronous in nature shall be considered in the torsional analysis, when applicable and shall be shown to have no adverse effect. Identification of these frequencies shall be the mutual responsibility of the purchaser and the vendor.

4.8.3.4 When torsional resonances are calculated to fall within the margin specified in 4.8.3.2, (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

● **4.8.3.5** When specified, the vendor shall perform a torsional vibration analysis of the complete coupled train and shall be responsible for directing the modifications necessary to meet the requirements of 4.8.3.1 through 4.8.3.4.

4.8.4 Vibration and Balancing

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

● **4.8.4.2** The rotating element shall be multiplane dynamically balanced during assembly. This shall be accomplished after adding no more than two major components. Balancing correction shall be applied only to the elements that are added. Other components may require minor corrections during the final trim balancing of the completely assembled element. On rotors that have single keyways, the keyway shall be filled with a fully crowned half-key. When specified, the weight of all half-keys used during the final balancing of the assembled element shall be recorded on the residual unbalance work sheet (Appendix C). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

$$U_{max} = 6350W/N \quad (1)$$

In U.S. Customary units:

$$U_{max} = 4W/N$$

Where:

U_{max} = residual unbalance, in gram-millimeters (ounce-inches).
W = journal static weight load, in kilograms (pounds).
N = maximum continuous speed, in revolutions per minute.

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

● **4.8.4.3** When specified, after the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance work sheet (Appendix C).

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

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

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

In U.S. Customary units:

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

Where:

A = amplitude of unfiltered vibration, in micrometers (mils) true peak to peak.

N = maximum continuous speed, in revolutions per minute.

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

Note: These limits are not to be confused with the limits specified in Appendix B for shop verification of unbalanced response.

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

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

4.8.4.7 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 percent of the test level calculated from Equation 2 or 6 micrometers (0.25 mil), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

4.8.4.8 When noncontacting vibration probes are not provided or when vibration cannot be measured on the shaft, the peak vibration velocity measured on the bearing housing while it operates at speeds described in 4.8.4.5 shall not exceed 3.0 millimeters (0.12 inch) per second (unfiltered) and 2.0 millimeters (0.08 inch) per second at running speed frequency (filtered).

4.9 BEARINGS AND BEARING HOUSINGS

4.9.1 Hydrodynamic radial bearings shall be required under the followings conditions:

a. Where antifricton-bearing *dN* factors are 300,000 or more. [A *dN* factor is the product of bearing size (bore) in millimeters and rated speed in revolutions per minute.]

b. When standard antifriction bearings fail to meet an L10 rating life (see ABMA Standard 9) of either 50,000 hours with continuous operation at rated conditions or 32,000 hours at maximum axial and radial loads and rated speed. (The rating life is the number of hours at the rated bearing load and speed that 90 percent of a group of identical bearings will complete or exceed before the evidence of failure.)

● **4.9.2** Horizontal turbines shall be equipped with thrust bearings designed to handle axial loads in either direction. Multistage turbines shall have hydrodynamic thrust bearings when specified or where antifriction bearings fail to meet the minimum L10 rating life (4.9.1, Item a).

4.9.3 Vertical turbines may have oil- or grease-lubricated ball- or roller- type radial and thrust bearings. Thrust bearings shall be designed for 200 percent of the driven-equipment thrust (up or down) specified on the data sheets. Antifriction bearings shall be protected against overgreasing.

4.9.4 Antifriction bearings shall be retained on the shaft and fitted into housings in accordance with the requirements of ABMA Standard 7; however, the device used to lock ball thrust bearings to the shaft shall be restricted to a nut with a tongue-type lock-washer, such as Series W.

4.9.5 Except for the angular contact type, antifriction bearings shall have a loose internal clearance fit equivalent to ABMA Symbol 3, as defined in ABMA Standard 20. Single- or double-row bearings shall be of the Conrad type (no filling slots).

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

4.9.7 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances to limit rotor vibration to the maximum specified amplitudes (4.8.4.5) while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency.

4.9.8 The liners, pads, or shells shall be in horizontally split housings and shall be replaceable without removing the top half of the casing of an axially split machine or the head of a radially split unit and without removing the coupling hub.

4.9.9 Bearings shall be designed to prevent their installation backwards and/or upside down.

4.9.10 Hydrodynamic thrust bearings shall be in accordance with 4.9.10.1 through 4.9.10.3.

4.9.10.1 Hydrodynamic thrust bearings shall be of the steel-backed, babbitted multiple-segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting-pad type, incorporating a self-leveling feature that assures that each pad carries an equal share of the thrust load with minor variation in pad thickness. Each pad shall be designed and manufactured with dimensional precision (thickness variation) that will allow interchange or replacement of individual pads.

4.9.10.2 Integral thrust collars are preferred for hydrodynamic thrust bearings. When integral collars are furnished, they shall be provided with at least 3 millimeters ($^1/_8$ inch) of additional stock to enable refinishing if the collar is damaged. When replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

4.9.10.3 Both faces of thrust collars for hydrodynamic thrust bearings shall have a surface finish of not more than 0.4 micrometers (16 microinches) R_a and the axial total indicated runout of either face shall not exceed 12 micrometers (0.0005 inch).

4.9.11 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculation of the thrust force 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 and exhaust pressure.
● e. External loads from the driven equipment, as described in 4.9.12 through 4.9.14 and as specified.

4.9.12 For gear-type couplings, the external thrust force shall be calculated from the following formula:

$$F = \frac{(0.25)(9{,}550)P_r}{(N_r D)}$$

In U.S. customary units:

$$F = \frac{(0.25)(63{,}000)P_r}{(N_r D)}$$

Where:

F = external force, in kilonewtons (pounds).
P_r = rated power, in kilowatts (horsepower).
N_r = rated speed, in revolutions per minute.
D = shaft diameter at the coupling, in millimeters (inches).

Note: Shaft diameter is an approximation of the coupling pitch radius.

4.9.13 Thrust forces for flexible-element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

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

4.9.15 Hydrodynamic thrust bearings shall be selected at no more than 50 percent of the bearing manufacturer's ultimate load rating. The ultimate load rating is the load that will produce the minimum acceptable oil-film thickness without inducing failure during continuous service or the load that will not exceed the creep initiation or yield strength of the babbitt at the location of maximum temperature on the pad, whichever load is less. In sizing thrust bearings, consideration shall be giving 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 turbulence of the oil film.

The calculated thrust load and the bearing manufacturers ultimate rating shall be provided on the data sheet.

4.9.16 Thrust bearings shall allow axial positioning of each rotor relative to the casing and setting of the thrust bearings' clearance or preload.

4.9.17 Axially split bearing housings shall have a metal-to-metal split joint whose halves are located by means of cylindrical dowels.

4.9.18 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-oil outlet 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.

4.9.19 Oil inlet and drain connections shall be flanged or machined and studded. Threaded openings are permissible in NPS $^3/_4$, 1, and $1^1/_2$. Pipe connections in NPS $1^1/_2$ inch tapped openings shall be installed as follows:

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

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

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

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

e. Pipe or tube fittings on NPS $^3/_4$ and 1 connections shall not be seal welded.

4.9.20 Tapped openings that may later be connected to customer piping shall be plugged with solid roundhead steel plugs furnished in accordance with ANSI B16.11. Thread tape shall not be used.

4.9.21 Bearing housings shall be equipped with replaceable end seals that effectively prevent the ingress of steam, condensation and foreign material through the area where the shaft passes through the housing. The seals shall be designed to effectively retain oil in the bearing housing. The seals shall be metallic, nonsparking, noncontact and nonwearing. Radial axial pattern seals and magnetic seals are acceptable. Lip-type seals shall not be used.

4.9.22 Bearing housings shall provide adequate protection against contamination by steam condensate, particularly during periods of idleness.

4.9.23 Bearing housings for oil-lubricated non-pressure-fed bearings shall be provided with tapped and plugged fill and drain openings at least NPS $^1/_2$ in size. The housing shall be equipped with constant-level sight-feed oilers at least 0.1 liter (4 ounces) in size, with a positive level positioner (not a set screw), heat-resistant glass containers, (not subject to sunlight- or heat-induced opacity or deterioration), and protective wire cages. A permanent indication of the proper oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or another durable means.

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

4.9.25 The requirements specified in 4.9.26 through 4.9.30 apply when oil mist lubrication is specified.

4.9.26 An NPS $^1/_4$ oil mist inlet connection, shall be provided in the top half of the bearing housing. The pure or purge oil mist fitting connections shall be located so that oil mist will flow through antifriction bearings. There shall be no internal passages to short-circuit oil mist from inlet to vent. If bearings are of the sleeve type, the connections for the condensing oil mist fittings shall be located over the bearings so the makeup oil will drip into the bearings.

4.9.27 An NPS $^1/_4$ vent connection, shall be provided on the housing or end cover for each of the spaces between antifriction bearings and the housing shaft closures. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

4.9.28 Shielded or sealed bearings shall not be used.

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

4.9.30 The oil mist supply and drain fittings will be provided by the purchaser.

4.9.31 Sufficient cooling capacity, including and allowance for fouling, shall be provided to maintain the oil temperature below 70°C (160°F) for pressurized systems and below 80°C (180°F) for ring-oiled or splash systems, based on the specified operation conditions and an ambient temperature of 40°C (110°F). Where cooling is required waterjackets shall have only external connections between the upper and lower housing jackets and shall have neither gasketed nor threaded connection joints, which may allow water to leak into the oil reservoir. If cooling coils (including fittings) are used, they shall be of nonferrous material and shall have no pressure joints or fittings internal to the bearing housing. Coils shall have a minimum thickness of at least 19 Birmingham wire gauge (BWG) [1 millimeter (0.042 inch)] and shall be at least 12 millimeters (0.50 inch) in diameter.

● **4.9.32** When specified, provision shall be made for mounting two 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 Standard 670 and shaft sensing areas shall conform to 4.6.2.

4.10 LUBRICATION

4.10.1 Unless otherwise specified, bearings and bearing housings for horizontal units shall be arranged for hydrocarbon oil lubrication.

4.10.2 Oil flinger disks or oil rings shall have an operating submergence of 3 to 6 millimeters ($^1/_8$ to $^1/_4$ inch) above the lower edge of a flinger or above the lower edge of the bore of an oil ring. Oil flingers shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

● **4.10.3** Where oil is supplied from a common system to two or more machines (such as a compressor, a gear, and a turbine), the oil's characteristics will be specified on the data sheets by the purchaser on the basis of mutual agreement with all vendors who supply equipment served by the common oil system.

Note: The usual lubricant employed in a common oil system is a hydrocarbon oil that corresponds to ISO Grade 32, as specified in ISO 3448.

● **4.10.4** Where a wide-speed-range, rapid-starting, or slow-roll operation is required, (mod) these conditions will be specified, and the driver vendor shall verify that adequate lubrication is available to the turbine (and gear) at all of these specified operating conditions.

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

4.10.6 Pressure lubrication systems other than those described in API Standard 614 shall consist of an oil pump with a suction strainer, a supply-and-return system, an oil cooler (when required), a full-flow filter, a low lube-oil pressure shutdown switch, and other necessary instruments. The requirements of 4.10.6.1 through 4.10.6.8 shall apply. See Appendix D for the minimum pressurized lube-oil system.

4.10.6.1 An austenitic stainless steel oil reservoir shall be supplied with the following characteristics and appendages:

a. The capacity to avoid frequent refilling and to provide adequate allowance for system rundown, and to provide a retention time of at least 3 minutes to settle moisture and foreign matter adequately.
b. Provisions to eliminate air and minimize flotation of foreign matter to pump suction.
c. Fill connection, armored gauge glass with level indication, and a breather suitable for outdoor use.
d. Sloped bottom and connection for complete drainage.
e. Clean out opening as large as practicable.

4.10.6.2 A main oil pump driven by the shaft, unless another source of pressurized oil is provided. Oil draining from the suction line during periods of idleness shall not cause damage to the pump during unattended start-up.

4.10.6.3 If required by the vendor, a hand-operated standby pump shall be provided for starting.

4.10.6.4 An oil cooler, preferably separate and of the shell-and-tube type. Oil coolers internal to the reservoir are not acceptable.

4.10.6.5 A full-flow filter with replaceable elements and filtration of 25 microns nominal or finer. Filter cartridge material shall be corrosion resistant. Metal-mesh or sintered-metal filter elements are not acceptable. Filters shall not be equipped with a relief valve or an automatic bypass.

4.10.6.6 A temperature gauge after the oil cooler.

4.10.6.7 Pressure gauges (valved for removal) to measure pressure before and after the filter.

4.10.6.8 Low-oil-pressure shutdown device or switch.

● **4.10.6.9** When specified by the purchaser or required by the vendor, a separately driven, automatically controlled standby pump.

● **4.10.6.10** When specified, a sight flow indicator in each bearing-oil drain line.

● **4.10.6.11** When specified, a low-oil-pressure alarm switch.

● **4.10.6.12** When specified, a low-oil-pressure auxiliary oil pump start switch.

4.10.7 Main and standby oil pumps shall have steel cases unless they are enclosed in a reservoir; however, casings of shaft-driven oil pumps may be made of iron. All other oil-containing pressure components shall be made of steel. (see 5.5.2 for lubricating-oil piping requirements.)

● **4.10.8** When specified, a removable steam-heating element external to the oil reservoir or a thermostatically controlled electric immersion heater with a sheath of AISI Standard Type 300 stainless steel shall be provided for heating the charge capacity of oil before start-up in cold weather. The heating device shall have sufficient capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 hours. If an electric immersion heater is used, it shall have a maximum watt density of 2.0 watts per square centimeter (15 watts per square inch).

4.11 MATERIALS

4.11.1 General

4.11.1.1 Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required or prohibited by the data sheets or this standard (see 5.5 for requirements for auxiliary piping materials). The metallurgy of all major components shall be clearly stated in the vendor's proposal.

4.11.1.2 Materials shall be identified in the proposal with their applicable ASTM, AISI, ASME, or SAE numbers, including the material grade. When no such designation is available, the vendor's material specification, giving physical properties, chemical composition, and test requirements, shall be included in the proposal.

4.11.1.3 Pressure parts shall be made of steel if the maximum steam conditions to which they may be subjected exceed 17 bar (250 pounds per square inch gauge) or 260˚C (500˚F). Exhaust casings of noncondensing turbines shall be made of steel if the maximum exhaust pressure may exceed 5.2 bar (75 pounds per square inch), or if the no-load exhaust temperature may exceed 260˚C (500˚F). Suitable alloy steel shall be used where the maximum steam temperatures may exceed 413˚C (775˚F). Ductile iron may be used only with the approval of the purchaser.

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

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

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

● **4.11.1.7** The purchaser will specify any corrosive agents that are present in the steam and the environment, including constituents that may cause stress corrosion cracking.

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

Note: Overlays or hard surfaces that contain more than 0.10 percent 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.

4.11.1.9 Where mating parts such as studs and nuts of AISI Type 300 stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and compatible with the specified fluid(s).

Note: Torque loading values will differ considerably with and without an antiseizure compound.

4.11.1.10 For the pressure casing, materials, casting factors, and the quality of any welding shall be equal to those required by Section VIII, Division 1, of the ASME Code. The manufacturer's data report forms, as specified in the code, are not required.

4.11.1.11 Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or low temperatures; therefore only fully killed, normalized steels made to fine-grain practice are acceptable. The use of ASTM A515 is prohibited.

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

4.11.1.13 The minimum quality bolting material for pressure joints shall be carbon steel (ASTM A 307, Grade B) for cast iron casings and high-temperature alloy steel (ASTM A 193, Grade B7) for steel casings. Nuts shall conform to ASTM A 194, Grade 2H (or ASTM A 307, Grade B, case hardened, where space is limited) for temperatures below -30˚C (-20˚F), low-temperature bolting material in accordance with ASTM A 320 shall be used.

4.11.2 Castings

4.11.2.1 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.

4.11.2.2 The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition that is compatible with the casting.

4.11.2.3 Ferrous castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 4.11.2.3.1 and 4.11.2.3.2.

4.11.2.3.1 Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure based on the requirements of Section VIII, Division 1, and Section IX of the ASME Code.

4.11.2.3.2 Gray cast iron or nodular iron may be repaired by plugging within the limits specified in ASTM A 278, A 395, or A 536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by ASTM specifications shall be subject to the purchaser's approval.

4.11.2.4 Fully enclosed cored voids, including voids closed by plugging are prohibited.

4.11.2.5 Nodular iron castings shall be produced in accordance with ASTM A 395.

4.11.3 Welding

4.11.3.1 Welding of piping and pressure-containing parts, as well as any dissimilar-metal welds and weld repairs, shall be performed and inspected by operators and procedures qualified in accordance with Section VIII, Division 1, and Section IX of the ASME Code.

4.11.3.2 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 (4.11.1.10). Repair welds shall be nondestructively tested by the same method used to detect the original flaw. As a minimum, the inspection shall be by the magnetic particle method in accordance with 6.2.2.4 for magnetic material and by the liquid penetrant method in accordance with 6.2.2.5 for non-magnetic material.

4.11.3.3 Unless otherwise specified, all welding other than that covered by Section VIII, Division 1, of the ASME Code and ASMW B31.3, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed in accordance with AWS D1.1.

4.11.3.4 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 4.11.3.4.1 through 4.11.3.4.4.

4.11.3.4.1 Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by Section VIII, Division 1, UG-93(d)(3), of the ASME Code.

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

4.11.3.4.3 Pressure-containing welds, including welds of the case to horizontal- and vertical-joint flanges, shall be full penetration welds.

4.11.3.4.4 Casings fabricated from materials that, according to Section VIII, Division 1, of the ASME Code, require post-weld heat treatment shall be heat treated regardless of thickness.

4.11.3.4.5 All welds shall be heat treated in accordance with Section VIII, Division 1, Sections UW-10 and UW-40, of the ASME Code.

4.12 NAMEPLATES AND ROTATION ARROWS

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

4.12.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location. Nameplates and rotation arrows (if attached) shall be of AISI Standard Type 300 stainless steel or of nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material. Welding is not permitted.

● **4.12.3** The purchaser shall specify whether U.S. customary or SI units are to be shown. The following data, as a minimum, shall be clearly stamped on the nameplate using the same units that are shown on the data sheets:

a. Vendor's name.
b. Serial number.
c. Size and type.
d. Rated power and speed.
e. First critical speed.
f. Second critical speed.

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

g. Maximum continuous speed.
h. Minimum allowable speed.
i. Overspeed trip setting.
j. Normal and maximum inlet steam temperature and pressure.
k. Normal and maximum exhaust steam pressure.
l. The purchaser's equipment item number (this may be on a separate nameplate if there is insufficient space on the rating nameplate).

5 Accessories

5.1 GEAR UNITS

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

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

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

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

5.2 COUPLINGS AND GUARDS

● **5.2.1** Unless otherwise specified, flexible element couplings and guards between turbines and driven equipment shall be supplied by the manufacturer of the driven equipment. If specified, the driver half of the coupling shall be mounted by the turbine manufacturer.

5.2.2 The power rating of the coupling-to-shaft juncture shall be at least equal to the driver's rated power times the coupling service factor for the application per AGMA 9002. The make, type, and mounting arrangement of the couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. A spacer coupling with a minimum 125-millimeter (5-inch) spacer shall be used, unless otherwise specified. Couplings shall be forged steel and designed to allow the necessary end float caused by expansion and other end movements of the shaft.

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

5.2.4 When the turbine vendor supplies a separate gear, he shall also furnish a flexible coupling between the gear and the turbine.

5.2.5 To assure accurate alignment of connected machinery, the total indicator reading of coupling registration and alignment surfaces shall be controlled as specified in 5.2.5.1 through 5.2.5.3.

5.2.5.1 For all turbines, the coupling surfaces normally used for checking alignment shall be concentric to the axis of coupling hub rotation within the following limits: 13 micrometers (0.0005 inch) TIR per inch of shaft diameter, with a minimum applicable tolerance of 25 micrometers (0.001 inch) TIR and a maximum of 75 micrometers (0.003 inch) TIR. All other diameters that are not used for locating, registration, or alignment shall conform to the coupling manufacturer's standard, provided that dynamic balance requirements are met.

5.2.5.2 For turbines connected to their driven equipment with a flexible coupling, the locating and alignment faces shall be perpendicular to the axis within the limits of 5.2.5.1.

5.2.5.3 For vertical turbines that have rigid couplings between the turbines and driven equipment, the coupling registration diameters shall be concentric within the limits stated in 5.2.6.1. Coupling registration faces shall be perpendicular to the axis of the coupling within 1 micrometer per 10 mm (0.0001 inch per inch) of face diameter with a maximum of 13 micrometers (0.0005 inch) TIR.

5.2.6 Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to ISO/R773 (ANSI/AGMA 9002, Commercial Class). Flexible couplings with cylindrical bores shall have the interference fit specified in ISO/R286, Tolerance N8, and shafting in accordance with ISO/R775 (ANSI/AGMA 9002). Where servicing the mechanical seal requires removal of the coupling hub, and the shaft diameter is greater than 60 millimeters (2.5 inches), the hub shall be mounted with a taper fit. Taper for keyed couplings shall be 1 in 10 *long series conical* in accordance with ISO/R775 or alternately 1 in 16 (0.75 in./ft., diametral) for compliance with U.S. Standards. Other mounting methods shall be agreed upon by the purchaser and the vendor. Coupling hubs shall be finished with tapped puller holes at least 10 millimeters ($^{3}/_{8}$ inch) in size to aid in removal.

Note: Appropriate assembly and maintenance procedures must be used to assure that taper fit couplings have an interference fit.

5.2.7 Couplings shall be manufactured to meet the requirements of ANSI/AGMA 9000 Class 9.

5.2.8 Couplings operating at speeds of 3,800 RPM or less shall be component balanced. Each component such as hubs, sleeves, flexible elements, spacers and adapters shall be balanced individually. All machining of components, except keyways of single-keyed hubs, shall be completed before balancing. Components shall be dynamically balanced to grade G1.0 of ISO 1940 or 7 gram-millimeters (.01 ounce-inches) whichever is greater. The weight of the arbor shall not exceed the weight of the component being balanced.

5.2.9 Couplings operating at speeds in excess of 3,800 revolutions per minute shall meet the requirements of API Standard 671 for component balancing and assembled balance check.

5.2.10 An easily removable coupling guard shall be placed over all exposed couplings furnished by the vendor. The coupling guard shall be of sufficiently rigid design to withstand deflection and consequent rubbing as a result of bodily contact and shall extend to within 13 millimeters (0.5 inch) of the stationary housing.

5.3 MOUNTING PLATES

5.3.1 General

● **5.3.1.1** When specified, the equipment shall be furnished with soleplates or a baseplate.

5.3.1.2 In 5.3.1.2.1 through 5.3.1.2.11, the term *mounting plate* refers to both baseplates and soleplates.

5.3.1.2.1 All machinery mounting surfaces on the mounting plates shall be machined flat and parallel after fabrication and shall extend at least 25 millimeters (1 inch) beyond the outer three sides of the equipment feet to prevent a soft foot. All surfaces on which a piece of equipment mounts shall be in the same plane within 50 micrometers

(0.002 inch). The maximum surface roughness shall be 3 micrometers (125 microinches) R_a.

5.3.1.2.2 When the equipment supported weighs more than 250 kilograms (500 pounds), the mounting plates shall be furnished with axial and lateral jackscrews the same size as or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so that the lugs do not interfere with the installation or removal of the equipment, jackscrews or shims. If the equipment is too heavy to use jackscrews, other means shall be provided.

5.3.1.2.3 Vertical jackscrews in the equipment feet shall be arranged to prevent marring of shimming surfaces.

5.3.1.2.4 Machinery supports shall be designed to limit a change of alignment caused by the worst combination of pressure, torque, and allowable piping stress to 50 micrometers (0.002 inch) at the coupling flange. (see 4.5 for allowable piping forces.)

5.3.1.2.5 When centerline supports are provided, they shall be designed and manufactured to permit the machine to be moved by using the horizontal jackscrews.

5.3.1.2.6 Unless otherwise specified, epoxy grout shall be used. The vendor shall commercially sandblast, in accordance with SSPC SP 6, all the grouting surfaces of the mounting plates and shall precoat these surfaces with an inorganic zinc silicate.

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

5.3.1.2.8 Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates shall be supplied with leveling screws. Mounting plates that are to be grouted shall be 50-millimeter-radiused (2-inch-radiused) outside corners (in the plan view). Mounting surfaces that are not to be grouted shall be coated with a rust preventative immediately after machining.

5.3.1.2.9 The vendor of the mounting plates shall furnish stainless steel (AISI Standard Type 300) shim packs 3 to 15 millimeters ($^1/_8$ to $^1/_2$ inch) thick between the equipment feet and the mounting plates. All shim packs shall straddle the hold down bolts and vertical jackscrews and be at least 5 millimeters ($^1/_4$ inch) larger on all sides than the footprint of the equipment.

5.3.1.2.10 Anchor bolts will be furnished by the purchaser.

5.3.1.2.11 Fasteners for attaching the equipment to the mounting plates and jackscrews for leveling the mounting plates shall be supplied by the vendor of the mounting plate.

5.3.2 Baseplate

5.3.2.1 When a baseplate is specified, the data sheets will indicate the major equipment to be mounted on it. The baseplate shall be single, fabricated steel unit. The baseplate shall be constructed with longitudinal steel beams and full-depth cross-members located underneath the support plane of the turbine and all turbine-driven equipment.

5.3.2.2 Unless otherwise specified, the baseplate shall extend under the drive-train components so that any leakage from these components is contained within the baseplate.

● **5.3.2.3** When specified, the baseplate shall be provided with leveling pads or targets protected with removable covers. The pads or targets shall be accessible for field leveling after installation, with the equipment mounted and the baseplate on the foundation.

● **5.3.2.4** When 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 baseplate design shall be mutually agreed upon by the purchaser and the vendor.

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

5.3.2.6 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, it shall be provided with at least one grout hole having a clear area of at least 0.01 square meter (20 square inches) and no dimension less than 75 millimeters (3 inches) 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 the turbine and driven equipment installed. The holes shall have 15-millimeter ($^1/_2$-inch) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least 15 millimeters ($^1/_2$ inch) in size shall be provided at the highest point in each bulkhead section of the baseplate.

5.3.2.7 In addition to the requirements of 5.3.2.6, anchor studs, such as "J" hooks, shall be welded to the underside of baseplate decks on maximum 300 millimeters (12 inch) centers to provide additional locking into the grout.

● **5.3.2.8** The mounting pads on the bottom of the baseplate shall be in one plane to permit use of a single-level foundation. When specified, subplates shall be provided by the vendor.

5.3.2.9 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

5.3.3 Soleplates and Subsoleplates

5.3.3.1 When soleplates are specified, they shall meet the requirements of 5.3.3.1.1 and 5.3.3.1.2 in addition to those of 5.3.2.

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

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

5.3.3.1.3 When subsoleplates are specified, they shall be steel plates at least 25 millimeters (1 inch) thick. The finish of the subsoleplates' mating surfaces shall match that of the soleplates (5.3.1.2.1).

5.4 CONTROLS AND INSTRUMENTATION

5.4.1 General

5.4.1.1 Instrumentation and its installation shall conform to detailed specifications in the purchaser's inquiry or order or both.

5.4.1.2 Unless otherwise specified, controls and instrumentation shall be suitable for outdoor installation.

5.4.1.3 Where applicable, controls and instrumentation shall conform to API Standard 670.

5.4.1.4 All conduit shall be designed and installed so that it can be easily removed without damage and located so that it does not hamper removal of bearings, seals, or equipment internals.

● **5.4.1.5** When specified, hand-operated nozzle control valves shall be supplied for economical operation at other than normal operating conditions. The vendor shall state the required number of hand valves and shall provide performance data (see 4.1.4.b).

5.4.2 Control Systems

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

5.4.2.2 Unless otherwise specified, a NEMA Class A oil-relay governor shall be supplied. The governor shall conform to NEMA SM 23 and shall have the same or better characteristics than those shown in Table 2. An electronic governor may be supplied.

Table 2—Speed Governors

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

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

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

● **5.4.2.4** When a control signal is specified for speed adjustment, the vendor shall provide a speed-setting mechanism arranged so that:

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

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

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

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

5.4.2.7 Trip and speed-governing valves shall have a metallic or other noncompressible type of bushing-valve stem packing and an intermediate leakoff when the maximum inlet steam pressure is 17 bar (250 psig) or higher.

5.4.2.8 The turbine shall be equipped with an independent emergency overspeed system that shuts off steam to the turbine when running speed reaches trip speed (see Table 2). The emergency trip system shall have the following characteristics:

a. Easy accessibility.

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

c. The capability to stop the turbine by activating a force-actuated trip valve under any load condition of the turbine.
d. The capability to be reset with maximum inlet pressure on the line.
e. Sparkproof components and suitability for use in hazardous gas and outdoor locations.

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

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

Note: For turbines that exhaust to subatmospheric pressure, even a closed emergency trip valve may leak enough steam to prevent the turbine and driven equipment from coming to a complete stop. A vacuum breaker will admit air to the exhaust casing, increase exhaust pressure, and reduce coast-down time. For turbines that exhaust to a common condensing system, the admission of air may not be feasible, and a more positive emergency trip valve or valves may be required.

5.4.3 Gauge Boards and Instrument Panels

● 5.4.3.1 Gauge Boards

When specified, a local gauge board shall be furnished. The purchaser will specify the extent of instrumentation required.

5.4.3.2 Instrument and Control Panels

● **5.4.3.2.1** When specified, a panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The purchaser will specify whether the panel is to be freestanding, located on the base of the unit, or in another location. The instruments on the panel shall be clearly visible to the operator from the driver control point. A lamp test push button shall be provided. The instruments to be mounted on the panel will be specified on the data sheets.

5.4.3.2.2 Panels shall be completely assembled, requiring only connection to the purchaser's external piping and wiring circuits. When more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box with terminal posts mounted on the unit (or its base, if any). Wiring shall be installed in metal conduits or enclosures. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification.

5.4.4 Instrumentation

● 5.4.4.1 Tachometers

When specified, a tachometer shall be provided. The type of tachometer, such as electrical or vibrating reed, will be specified. Unless otherwise specified, the minimum tachometer range shall be from 0 to 125 percent of the maximum continuous speed.

5.4.4.2 Temperature Gauges

5.4.4.2.1 Dial-type temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 100 millimeters (5 inches) in diameter and bimetallic type or liquid filled. Black printing on a white background is standard for gauges.

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

Note: This is particularly important in lines that may run partially full.

5.4.4.3 Thermowells

Temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with NPS $^3/_4$ AISI Standard Type 300 stainless steel separable solid-bar thermowells.

5.4.4.4 Thermocouples and Resistance Temperature Detectors

Where practical, the design and location of thermocouples and resistance temperature detectors shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box. Conduit runs from thermocouple heads to a pull box or boxes located on the baseplate shall be provided.

5.4.4.5 Pressure Gauges

5.4.4.5.1 Pressure gauges (not including built-in instrument air gauges) shall be furnished with AISI Standard Type 316 stainless steel bourdon tubes and stainless steel movements, 110-millimeter ($4^1/_2$-inch) dials [150-millimeter (6-inch) dials for the range over 55 bar (800 pounds per square inch)], and NPS male alloy steel connections. Black printing on a white background is standard for gauges.

Gauge ranges shall preferably be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 percent. Each pressure gauge shall be provided with a device such as a disk insert or blowout back designed to relieve excess case pressure.

● **5.4.4.5.2** When specified, liquid-filled gauges shall be furnished in locations subject to vibration.

5.4.4.6 Solenoid Valves

Direct solenoid-operated valves shall be used only in clean, dry instrument-air service, shall have Class F insulation or better, and shall have a continuous service rating. When required for other services, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves, and the like.

5.4.4.7 Relief Valves

5.4.4.7.1 The vendor shall furnish the relief valves that are to be installed on equipment or in piping that the vendor is supplying. Other relief valves will be furnished by the purchaser. Relief valves for all operating equipment shall meet the limiting relief valve requirements defined in API Recommended Practice 520, Parts I and II, and in API Standard 526. The vendor shall provide flow rate, maximum allowable 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. Relief valve settings, including accumulation, shall take into consideration all possible types of equipment failures and the protection of piping systems.

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

● **5.4.4.7.3** When specified, thermal relief valves shall be provided for components that may be blocked in by isolation valves.

5.4.4.8 Flow Indicators

● **5.4.4.8.1** When specified, flow indicators shall be furnished in the atmospheric oil-drain return line from each bearing.

5.4.4.8.2 Unless otherwise specified, the flow indicator shall be flanged, shall be of the bull's-eye type, and shall have a steel body.

5.4.4.8.3 To facilitate viewing of the flow of oil through the line, each flow indicator should be installed with its bull's-eye glass in a vertical plane. The diameter of the bull's-eye shall be at least one-half the inside diameter of the oil pipe and shall clearly show the minimum oil flow.

5.4.5 Alarms and Shutdowns

● 5.4.5.1 General

Switches and control devices shall be furnished and mounted by the vendor, as specified.

● 5.4.5.2 Sentinel Warning Valves

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

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

5.4.5.3 Alarm and Trip Switches

5.4.5.3.1 Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance. Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 amperes at 120 volts AC and $^1/_2$ ampere at 120 volts DC shall be used. Mercury switches shall not be used.

● **5.4.5.3.2** The purchaser will specify the actuation of electrical switches for alarm and trip functions.

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

5.4.5.3.4 Pressure-sensing elements shall be of AISI Standard Type 300 stainless steel.

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

5.4.5.4 Housings for Arcing-Type Switches

Particular attention is called to the requirements of 4.1.13 concerning the characteristics of housings for arcing-type switches outlined in the applicable codes.

5.4.6 Vibration and Position Detectors

● **5.4.6.1** When specified, vibration and axial-position transducers shall be supplied, installed, and calibrated in accordance with API Standard 670.

● **5.4.6.2** When specified, vibration and axial position monitors shall be supplied and calibrated in accordance with API Standard 670.

● **5.4.6.3** When specified, a bearing-temperature monitor shall be supplied and calibrated in accordance with API Standard 670.

5.5 PIPING AND APPURTENANCES

5.5.1 General

5.5.1.1 Piping design, joint fabrication, examination, and inspection shall be in accordance with ASME B31.3. Unless otherwise specified, radiographic examination is not required.

5.5.1.2 Auxiliary systems are defined as piping systems that are in the following services:

a. Steam, including sealing steam.
b. Instrument and control air.
c. Lubricating oil.
d. Control oil.

e. Cooling water.
f. Drains and vents.

Auxiliary systems shall comply with the requirements of Table 3.

Note: Casing connections are discussed in 4.4.

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

5.5.1.4 When the turbine vendor provides the baseplate, all piping systems for the equipment provided by the turbine vendor, including mounted appurtenances that are located within the confines of the main unit's base area, any console base area, or any auxiliary base area, shall be furnished. The piping shall terminate with flanged connections at the edge of each base.

5.5.1.5 The design of piping systems shall achieve the following:

a. Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.
b. Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.
c. Installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access openings.
d. Elimination of air pockets.
e. Complete drainage through low points without disassembly of piping.

5.5.1.6 Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Welded flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Threaded connections shall be held to a minimum. Pipe bushings shall not be used.

5.5.1.7 Pipe threads shall be taper threads in accordance with ASME B1.20.1. Alternately, pipe threads in accordance with ISO 228 Part 1 are acceptable when required for compliance with local standards. Flanges shall be in accordance with ISO 7005 (ASME B16.5). Slip-on flanges are permitted only with the purchaser's specific approval. For socket-welded construction, a 1.5-millimeter ($^1/_{16}$-inch) gap shall be left between the pipe end and the bottom of the socket.

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

5.5.1.9 Connections, piping, valves, and fittings that are 30 millimeters ($1^1/_4$ inches), 65 millimeters ($2^1/_2$ inches), 90 millimeters ($3^1/_2$ inches), 125 millimeters (5 inches), 175 millimeters (7 inches) or 225 millimeters (9 inches) in size shall not be used.

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

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

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

5.5.2 Oil Piping

5.5.2.1 Oil drains shall be sized to run no more than half full when flowing at a velocity of 0.3 meter per second (1 foot per second) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously, at least 40 millimeters per meter ($^1/_2$ inch per foot), toward the reservoir. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45 degree angles in the direction of the flow.

5.5.2.2 Nonconsumable backup rings and sleeve-type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that could accumulate dirt. Socket-welded fittings shall not be used in pressure piping downstream of oil filters.

5.6 SPECIAL TOOLS

5.6.1 When special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be mutually 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.

5.6.2 When special tools are provided, they shall be packaged in separate, rugged boxes and marked *special tools for* (tag/item number). Each tool shall be tagged to indicate its intended use.

5.7 INSULATION AND JACKETING

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

Table 3—Minimum Requirements for Piping Materials

	Steam		Cooling Water		Lube Oil	
System	≤75 pounds per square inch gauge	>75 pounds per square inch gauge	Standard (≤NPS 1)	Optional	≤NPS 1	≥NPS $1^1/_2$
Pipe	Seamless[a]	Seamless[a]		ASTM A 53 Type F Schedule 40, galvanized to ASTM A 153		ASTM A 312, Type 304 or 316 stainless steel[b]
Tubing	ASTM A 269, seamless Type 304 or 316 stainless steel[c]		ASTM A 269, seamless Type 304 or 316 stainless steel[c]		ASTM A 269, seamless Type 304 or 316 stainless steel[c]	
All Valves	Carbon steel, Class 800	Carbon steel, Class 800	Bronze, Class 200	Bronze, Class 200	Carbon steel, Class 800	Carbon steel, Class 800
Gate and Globe Valves	Bolted bonnet and gland	Bolted bonnet and gland			Bolted bonnet and gland	Bolted bonnet and gland
Pipe Fittings and Unions	Forged, Class 3000	Forged, Class 3000	ASTM A 338 and A 197, Class 150 malleable iron, galvanized to ASTM A 153	ASTM A 338 and A 197, Class 150 malleable iron, galvanized to ASTM A 153	Stainless steel	Stainless steel
Tube Fittings	Carbon steel, compression, manufacturer's standard		Manufacturer's standard		Carbon steel, compression, manufacturer's standard	
Fabricated joints ≤$1^1/_2$ inches	Threaded	Socket welded	Threaded	Threaded		Carbon steel slip-on flange
Fabricated joints ≥2 inches	Slip-on flange	Socket-weld or weld-neck flange	Purchaser to specify	Purchaser to specify		Carbon steel slip-on flange
Gaskets	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel				Type 304 or 316 stainless steel, spiral wound
Flange bolting	ASTM A 193, Grade B7 ASTM A 194, Grade 2H	ASTM A 193, Grade B7 ASTM A 194, Grade 2H				ASTM A 193, Grade B7 ASTM A 194, Grade 2H

Note:
Carbon steel piping shall conform to ASTM A 106, Grade B; ASTM A 524; or API Specification 5L, Grade A or B.
Carbon steel fittings, valves, and flanged components shall conform to ASTM A 105 and A 181. Stainless steel piping shall conform to ASTM A 312.

[a] Schedule 80 for diameters from $^1/_2$ inch to $1^1/_2$ inches; Schedule 40 for diameters 2 inches and larger.
[b] Schedule 40 for a diameter of $1^1/_2$ inches; Schedule 10 for diameters of 2 inches and larger.
[c] $^1/_2$-inch diameter x 0.065-inch wall, $^3/_4$-inch diameter x 0.095-inch wall, or 1-inch diameter x 0.109-inch wall.

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

6 Inspection and Testing

6.1 GENERAL

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

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

6.1.3 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.

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

● **6.1.5** The purchaser will specify the extent of participation in the inspection and testing and the amount of advance notification required.

6.1.5.1 When 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.

6.1.5.2 *Witnessed* means that a hold shall be applied to the production schedule and the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance tests, this requires written notification of a successful preliminary test.

6.1.5.3 *Observed* means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

6.1.6 Equipment for the specified inspection and tests shall be provided by the vendor.

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

6.2 INSPECTION

6.2.1 General

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

6.2.1.2 Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

● **6.2.1.3** In addition to the requirements of 4.11.3.1, the purchaser will 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, and ultrasonic examination.

6.2.2 Material Inspection

6.2.2.1 General

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

6.2.2.1.2 When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 6.2.2.2 through 6.2.2.5 shall apply unless other criteria are specified by the purchaser. Cast iron may be inspected in accordance with 6.2.2.4 and 6.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 6.2.2.2 through 6.2.2.5.

6.2.2.2 Radiography

6.2.2.2.1 Radiography shall be in accordance with ASTM E 94 and ASTM E 142.

6.2.2.2.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-51 (100 Percent) and UW-52 (SPOT), of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

6.2.2.3 Ultrasonic Inspection

● **6.2.2.3.1** When specified, all forgings and bar stock for major rotating elements shall be 100-percent ultrasonically inspected after rough machining in accordance with ASTM A 388. Acceptable criteria shall be mutually agreed upon by the purchaser and the vendor.

6.2.2.3.2 Ultrasonic inspection shall be in accordance with Section V, Articles 5 and 23, of the ASME Code.

6.2.2.3.3 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 12, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

6.2.2.4 Magnetic Particle Inspection

6.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E 709.

6.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 6 and Section V, Article 25, of the ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 4.

Table 4—Maximum Severity of Defects in Castings

Type	Defect	Maximum Severity Level
I	Linear discontinuities	1
II	Shrinkage	2
III	Inclusions	2
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

6.2.2.5 Liquid Penetrant Inspection

6.2.2.5.1 Liquid penetrant inspection shall be in accordance with Section V, Article 6, of the ASME Code.

6.2.2.5.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 8 and Section V, Article 24, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

Note: Regardless of the generalized limits in 6.2.2, it shall be the vendor's responsibility to review the design limits of the equipment in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 6.2.2 shall be removed to meet the quality standards cited, as determined by the inspection method specified.

6.2.3 Mechanical Inspection

6.2.3.1 During assembly of the equipment and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically, or by another appropriate method, to remove foreign materials, corrosion products, and mill scale.

6.2.3.2 Any portion of the oil system furnished with the turbine shall meet the cleanliness requirements of API Standard 614.

6.3 TESTING

6.3.1 General

6.3.1.1 Equipment shall be tested in accordance with 6.3.2 and 6.3.3. Other tests that may be specified by the purchaser are described in 6.3.4.

6.3.1.2 The vendor shall notify the purchaser not less than 5 working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than 5 working days before the new test date.

6.3.2 Hydrostatic Test

6.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1.5 times the maximum allowable working pressure but not less than a gauge pressure of 1.5 bar (20 pounds per square inch gauge). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

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

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

6.3.2.3 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 15 minutes. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

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

6.3.2.5 No coatings (primer or finish) shall be applied to any components prior to hydrotest.

6.3.3 Mechanical Running Test

6.3.3.1 The requirements of 6.3.3.1.1 through 6.3.3.1.9 shall be met before the mechanical running test is performed.

6.3.3.1.1 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.

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

6.3.3.1.3 Test-stand oil filtration shall be 25 microns nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of API Standard 614 before any test is started.

6.3.3.1.4 Bearings used in oil mist lubrication systems shall be prelubricated.

6.3.3.1.5 When noncontacting probes are not provided and when vibration cannot be measured on the shaft, radial vibration of the housings shall be recorded using shop instrumentation during the test. The measurements shall be taken on the top and side of each bearing housing (see 4.8.4.8 for vibration velocity limits).

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

6.3.3.1.7 The vibration characteristics determined by the use of the instrumentation specified in 6.3.3.1.5 or 6.3.3.1.6 shall serve as the basis for acceptance or rejection of the machine (4.8.4.5 and 4.8.4.8).

6.3.3.1.8 All joints and connection shall be checked for tightness, and any leaks shall be corrected.

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

6.3.3.2 Turbines shall be given a 1-hour uninterrupted no-load running test at maximum continuous speed.

6.3.3.3 Unless otherwise specified, the control system shall be demonstrated and the mechanical running test of the steam turbine shall be conducted as specified in 6.3.3.3.1 through 6.3.3.3.7.

6.3.3.3.1 Steam conditions shall be as close to design as practical.

Note: 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.

6.3.3.3.2 The equipment shall be operated at speed increments of approximately 10 percent from zero to the maximum continuous speed and run at the maximum continuous speed until bearings, lube-oil temperatures and shaft vibrations have stabilized.

6.3.3.3.3 The speed shall be increased to 110 percent of the maximum continuous speed, and the equipment shall be run for a minimum of 15 minutes at the increased speed.

6.3.3.3.4 Vibration readings shall be taken at maximum continuous speed, just below trip speed, and at minimum operating speed after the stabilization described in 6.3.3.3.2. Maximum allowable vibration limits are described in 4.8.4.5 or 4.8.4.8 as applicable. Any critical speeds below maximum continuous shall be determined. Vibration limits for operation just below trip speed for turbines covered by 4.8.4.8 are 1.5 times the stated values.

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

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

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

6.3.3.4 Unless otherwise specified, the requirements of 6.3.3.4.1 through 6.3.3.4.3 shall be met after the mechanical running test is completed.

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

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

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

● **6.3.4 Optional Tests**

When specified, the shop tests described in 6.3.4.1 through 6.3.4.5 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

● **6.3.4.1 Performance Tests**

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

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

● **6.3.4.2 Complete-Unit Test**

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

● **6.3.4.3 Gear Test**

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

● **6.3.4.4 Sound-Level Test**

The sound-level test shall be performed in accordance with the purchaser's requirements.

● **6.3.4.5 Auxiliary-Equipment Test**

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

6.4 PREPARATION FOR SHIPMENT

● **6.4.1** Equipment shall be suitably prepared for the type of shipment specified, including blocking of the rotor when necessary. The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

6.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

6.4.3 The equipment shall be prepared for shipment after all testing and inspection has been completed. The preparation shall include that specified in 6.4.3.1 through 6.4.3.13.

6.4.3.1 Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.

6.4.3.2 Exterior machined surfaces shall be coated with a suitable rust preventive.

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

6.4.3.4 Internal steel areas of bearing housings and the oil side of oil system equipment, such as filters and coolers, shall be coated with a suitable oil-soluble rust preventive.

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

6.4.3.6 Threaded openings shall be provided with caps or round-head plugs. In no case shall nonmetallic (such as plastic) caps or plugs be used.

Note: These are shipping plugs; permanent plugs are covered in 4.4.5.

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

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

6.4.3.9 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 one on the outside of the shipping container.

6.4.3.10 When a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 3 years. The rotor shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor. Suitable resilient material 3-millimeters ($^{1}/_{8}$-inch) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)], shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

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

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

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

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

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

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

7 Vendor's Data

7.1 GENERAL

7.1.1 The information to be furnished by the vendor is specified in 7.2 and 7.3. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix E) 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.

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

a. The purchaser/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 identify return correspondence completely.

7.2 PROPOSALS

7.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 7.2.2 through 7.2.3, as well as a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 7.1.2.

7.2.2 Drawings

7.2.2.1 The drawings indicated on the Vendor Drawing and Data Requirements form (see Appendix E) shall be included in the proposal. As a minimum, the following drawings shall be furnished:

a. A preliminary dimensional outline drawing that shows available locations of inlet and exhaust openings.
b. Cross-sectional or exploded view drawings showing the details of the proposed equipment.
c. Schematic diagrams of the lube-oil system and gland-sealing system when furnished by the turbine vendor.
d. Sketches that show methods of lifting the assembled machine or machines and major components. (This information may be included on the drawings specified in Item a above.)

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

7.2.3 Technical Data

The following data shall be included in the proposal:

a. a. The purchaser's data sheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.
b. The purchaser's noise data sheet.
c. The Vendor Drawing and Data Requirements form (Appendix E), indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.
d. A schedule for shipment of the equipment, in weeks after receipt of the order.
e. A list of major wearing components, showing interchangeability with the purchaser's other units.
f. A list of spare parts recommended for start-up and normal maintenance purposes.

g. A list of the special tools furnished for maintenance. The vendor shall identify any metric items included in the offering.

h. A statement of any special weather protection and winterization required for start-up, operation and periods of idleness under the site conditions specified on the data sheets. The list shall show the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply.

i. A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas and lube oil, including the quantity of lube oil required and the supply pressure, 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.)

j. A description of the tests and inspection procedures for materials, as required.

k. A description of any special requirements specified in the purchaser's inquiry and as outlined in 4.11.1.1, 4.11.1.2, and 5.4.4.7.1.

l. A list of similar machines installed and operating under conditions analogous to those specified in the proposal.

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

n. Alarm and shut down facilities.

o. Lateral critical speed values.

7.2.4 Curves

● When specified, the vendor shall provide the following performance curves:

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

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

7.3 CONTRACT DATA

7.3.1 General

7.3.1.1 The contract data to be furnished by the vendor is specified in Appendix E. Each drawing, bill of material, and data sheet shall have a title block in its lower right hand corner that shows the date of certification, a reference to all identification data specified in 7.1.2, the revision number and date, and the title (see 7.3.2, 7.3.3).

7.3.1.2 The purchaser will promptly review the vendor's data when he receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically, agreed upon in writing. After the data have been reviewed, the vendor shall furnish certified copies in the quantity specified.

7.3.1.3 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all the data the vendor will furnish (see Appendix E).

7.3.2 Drawings

The drawings furnished shall contain sufficient information so that with the drawings and the manuals specified in 7.3.6, the purchaser can properly install, operate, and maintain the ordered equipment. Drawings shall be clearly legible, shall be identified in accordance with 7.3.1.1, and shall be in accordance with ASME Y14.2M. As a minimum, each drawing shall include the details for that drawing listed in Appendix E.

7.3.3 Technical Data

The data shall be submitted in accordance with Appendix E and identified in accordance with 7.3.1.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations will result in the purchaser's issue of completed, corrected data sheets as part of the order specifications.

7.3.4 Progress Reports

The vendor shall submit progress reports to the purchaser at the intervals specified on the Vendor Drawing and Data Requirements form (see Appendix E).

7.3.5 Parts Lists and Recommended Spares

7.3.5.1 The vendor shall submit complete parts lists for all equipment and accessories supplied, the lists shall include manufacturer's unique part numbers, materials of construction and delivery times, materials shall be identified as specified in 4.11.1.2. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the purchaser may determine the interchangeability of the part with other equipment, parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items shall be identified by the original manufacturer's name and part number.

7.3.5.2 The vendor shall indicate on the above parts lists which parts are recommended spares for normal maintenance (see item f of 7.2.3). 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. The transmittal letter shall be identified with the data specified in 7.1.2.

7.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

7.3.6.1 General

The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference-identifying data specified in 7.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation; a typical manual is not acceptable.

7.3.6.2 Installation Manual

Any special information required for proper installation design that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time that is mutually agreed upon in the order but not later than the final issue of prints. The manual shall contain information such as special alignment and grouting procedures, utility specifications (including quantities), and all other installation design data, including the drawings and data specified in 7.2.2 and 7.2.3. The manual shall also include sketches that show the location of the center of gravity and rigging provisions to permit the removal of the top half of the casings, rotors, and any subassemblies that weigh more than 135 kilograms (300 pounds).

7.3.6.3 Operating and Maintenance Manual

The manual containing operating and maintenance data shall be forwarded no more than 2 weeks after all of the specified tests have been successfully completed. This manual shall include a section that provides special instructions for operation at specified extreme environmental conditions, such as temperatures. As a minimum, the manual shall also include all of the data listed in Appendix E.

● 7.3.6.4 Technical Data Manual

When specified, the vendor shall provide the purchaser with a technical data manual within 30 days of completion of shop testing. (see Appendix E).

APPENDIX A—GENERAL PURPOSE STEAM TURBINE DATA SHEETS

GENERAL-PURPOSE STEAM TURBINE
DATA SHEET
SI UNITS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______
SPECIFICATION NO. ______
REVISION NO. ______ DATE ______
 BY ______

1	APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT	
2	FOR	UNIT
3	SITE	NO. REQUIRED
4	SERVICE	DRIVEN EQUIPMENT
5	MANUFACTURER	MODEL ______ SERIAL NO.
6	**NOTE: ○ INDICATES INFORMATION COMPLETED BY PURCHASER**	**☐ BY MANUFACTURER ⊡ BY MFGR IF NOT BY PURCHASER**
7	**○ OPERATING CONDITIONS**	**☐ PERFORMANCE**
8	**OPERATING POINT | POWER, kW | SPEED, RPM**	**OPERATING POINT/ STEAM CONDITION | NO. HAND VALVES OPEN (5.4.1.4) | STEAM RATE, kg/kW-HR**
9		
10	NORMAL	NORMAL/NORMAL
11		(CERTIFIED SR)
12	RATED	RATED/NORMAL
13	OTHER (4.1.4)	(1) MIN. INLET -
14	**○ DUTY, SITE AND UTILITY DATA**	MAX EXHAUST
15	APPLICATION IS (SPARED, UNSPARED) ______	(1) ○ RATED ○ ______% RATED ○ NORMAL (4.1.4)
16	○ WIDE SPEED RANGE ○ RAPID START	**APPLICABLE SPECIFICATION**
17	○ SLOW ROLL REQ. (4.10.4) ○ HAND VALVES REQ. (5.4.1.5)	API-611 OTHER ______
18	DUTY ○ CONTINUOUS ○ STANDBY	
19	○ UNATTENDED AUTO START (4.1.6)	**CONSTRUCTION**
20	LOCATION (4.1.14) ○ INDOOR ○ HEATED ○ UNHEATED	TURBINE TYPE ○ HORIZ ○ VERTICAL
21	○ OUTDOOR ○ ROOF ○ W/O ROOF	NO STAGES ______ WHEEL DIA., mm ______
22	AMBIENT TEMP., °C: MIN. ______ MAX ______	ROTOR: ☐ BUILT UP ☐ SOLID ☐ OVERHUNG
23	UNUSUAL CONDITIONS ○ DUST ○ SALT ATMOSPHERE	☐ BETWEEN BRGS
24	(4.1.14) ○ OTHER ______	BLADING ☐ 2 ROW ☐ 3 ROW ☐ RE-ENTRY
25	ELECT. AREA (4.1.13) CLASS ______ GROUP ______ DIV ______	CASING SPLIT ☐ AXIAL ☐ RADIAL
26	○ NON-HAZARDOUS	CASING SUPPORT ☐ CENTERLINE ☐ FOOT
27	CONTROL POWER V ______ PH. ______ HZ ______	○ VERT. JACKSCREWS (4.2.13)
28	AUX. MOTORS V ______ PH. ______ HZ ______	VERTICAL TURBINE FLANGE
29	COOLING WATER: PRESS, BARG ______ Δ P, PSI ______	○ NEMA "P" BASE ○ OTHER (4.4.9) ______
30	FLOW, m^3/hr ______ Δ T, °C: ______	TRIP VALVE ☐ INTEGRAL ☐ SEPARATE
31	ALLOW. SOUND PRESS LEVEL (4.1.12) ______ dBA @ ______ m	INTERSTAGE SEALS ☐ LABYRINTH ☐ CARBON
32	**○ STEAM CONDITIONS**	END SEALS ☐ CARBON RING, NO/BOX ______
33	**| MAX | NORMAL | MIN.**	☐ LABYRINTH ☐ MATERIAL ______
34	INLET PRESS, (BARG)(kPa G)	☐ MECHANICAL ☐ MFB ______
35	INLET TEMP,°C	TYPE RADIAL BEARINGS (4.9.1) ______
36	EXHAUST PRESS (BARG) (mmHGA)	TYPE THRUST BEARING (4.9.2) ______
37	○ STEAM CONTAMINANTS (4.11.1.7)	☐ CALCULATED THRUST LOAD ______ BAR (4.9.15)
38	**TURBINE DATA**	☐ BEARING MFGR's ULTIMATE RATING ______ BAR
39	☐ ALLOW SPEEDS, RPM, MAX ______ MIN ______	THRUST COLLAR (4.9.10.2) ☐ REPLACEABLE ☐ INTEGRAL ☐ NONE
40	☐ MAX CONT SPEED, RPM (3.1.10) ______	⊡ LUBE OIL VISCOSITY (4.10.3) ISO GRADE ______
41	☐ TRIP SPEED, RPM ______ BLADE TIP VEL, mm/s ______	LUBRICATION ○ RING OILED ○ PRESSURE ○ GREASE
42	☐ FIRST CRITICAL SPEED, RPM (4.8.2.1) ______	OIL MIST (4.9.19)
43	☐ EXH. TEMP °C ______ NORMAL ______ NO LOAD	○ PURGE OIL MIST ○ PURE OIL MIST
44	☐ POTENTIAL MAX POWER, KW (3.1.20) ______	○ BEARING HOUSING OILER TYPE ______
45	☐ MAX. NOZZLE STEAM FLOW, kg/hr ______	**CASING DESIGN | INLET | EXHAUST**
46	ROTATION FACING GOVERNOR END ○ CCW ○ CW	MAX. ALLOW. PRESS, BARG
47	○ DRIVEN EQUIPMENT THRUST, N (4.9.11) ______	MAX ALLOW. TEMP, °C
48	(VERTICAL TURBINE) (4.9.3)	HYDRO TEST PRESS., BARG
49	○ WATER PIPING FURN. BY ○ VENDOR ○ OTHERS	
50	○ OIL PIPING FURN. BY ○ VENDOR ○ OTHERS	

GENERAL-PURPOSE STEAM TURBINE
DATA SHEET
SI UNITS

☐ MATERIALS

HIGH PRESSURE CASING ______ GRADE ______

EXHAUST CASING ______ GRADE ______

NOZZLES ______ GRADE ______

BLADING ______ GRADE ______

WHEELS ______ GRADE ______

SHAFT ______ GRADE ______

○ SHAFT COATING UNDER PACKING (4.6.2.3)

MATERIAL ______

APPLICATION METHOD ______

THICKNESS ______

GOV. VALVE TRIM ______

INLET STRAINER ______ MESH SIZE ______

COUPLING SPACER/HUBS ______

COUPLING DIAPHRAGMS (DISKS) ______

STEAM CONTROL

SPEED CHANGER ○ MANUAL ○ PNEUM. ○ ELECT (5.4.2.3)

MFR. ______ MODEL ______

CONTROLLED VARIABLE	OPERATING RANGE	CONTROL SIGNAL
SPEED	___ TO ______ RPM	___ TO ______ BARG/mA
	___ TO ______ RPM	___ TO ______ BARG/mA

☐ CONNECTIONS (4.4.1)

	SIZE	RAT'G	FAC'G	POS.	○ MATING PARTS FURNISHED (4.4.6.5)
INLET					
EXHAUST					
DRAINS					

COUPLINGS (5.2) ○ SEE SEPARATE DATA SHEET

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

○ TURBINE VENDOR MOUNTS HALF COUPLING

DYN. BALANCE CL (5.2.8)

○ AGMA CLASS 8 ○ OTHER ______

TURBINE SHAFT ☐ TAPER ☐ STRA'T ☐ HYDRAULIC FIT HUB

○ MOUNTING PLATES

TYPE: (5.3.1.1) ○ BASEPLATE ○ SOLEPLATE

FURN. BY: ○ TURBINE VENDOR

○ DRIVEN EQUIPMENT VENDOR ○ OTHER ______

EQUIPMENT TO BE MOUNTED: (5.3.2.1)

○ TURBINE ○ GENERATOR ○ GEAR

○ PUMP ○ OTHER ______

○ UNGROUTED BASEPLATE (5.3.2.4)

○ SUITABLE FOR COLUMN MOUNTING

○ TURBINE VENDOR FURNISHES SUBPLATES

○ ACCESSORY EQUIPMENT BY VENDOR

○ REMOTE TRIP ○ SOLENOID

☐ VACUUM BREAKER (5.4.2.9)

○ AUTOMATIC STEAM SEALING SYSTEM (4.7.5)

GLAND VACUUM DEVICE WITH: (4.7.4)

○ WATER EDUCTOR ○ STEAM EJECTOR

○ SENTINEL WARNING VALVE (5.4.5.2)

☐ INSULATION, TYPE: ______

○ TACHOMETER (5.4.4.1), TYPE ______

○ MFR. ______ ○ MODEL ______

○ MOUNTED BY ______

○ THERMAL RELIEF VALVES (5.4.4.7.3)

○ SHUTOFF VALVES FOR SHUTDOWN SENSORS

○ LOCAL GAUGE BOARD WITH FOLLOWING PRESSURE GAUGES: (5.4.3.1)

○ THROTTLE STEAM ○ FIRST STAGE

○ NOZZLE RING ○ EXHAUST

○ LIQUID FILLED GAUGES (5.4.4.4)

○ INSTRUMENT PANEL (5.4.3.2.1)

○ BASEMOUNT

○ FREE STANDING

EXTERNAL LUBE OIL SYSTEM

☐ CIRCULATING (4.10.5) ○ PRESSURE (4.10.6)

VENDOR FURNISH SYSTEM FOR: ○ TURBINE

○ OTHER ______

OIL SYSTEM TO BE: ○ CONSOLE TYPE

○ MOUNTED ON BASEPLATE

OIL SYSTEM TO INCLUDE FOLLOWING EQUIPMENT: (4.10.5)(4.10.7)

○ STANDBY OIL PUMP: TYPE DRIVER ______

○ LOW OIL PRESS ALARM SWITCH

○ LOW OIL PRESS TRIP SWITCH

○ HEATER (4.10.8) ○ ELECTRIC ○ STEAM

○ OIL DRAIN SIGHT FLOW INDICATORS

☐ HAND OPERATED STANDBY PUMP

VIBRATION AND POSITION DETECTORS (5.4.6)

○ FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING VIBRATION PROBES (4.9.32)

○ FURN. AXIAL POSITION PROBES ○ NO. OF PROBES ______

○ MFR. ______ ○ MODEL ______

○ FURN. RADIAL PROBES ○ NO. OF PROBES PER BEARING ______

○ MFR. ______ ○ MODEL ______

FURNISH BEARING METAL TEMP SENSORS FOR:

○ RADIAL BEARINGS ○ THRUST BEARINGS

TURBINE VENDOR SUPPLIES AND CALIBRATES MONITORS FOR:

○ AXIAL AND RADIAL PROBES

○ BEARING TEMPERATURE SENSORS

○ SEE SEPARATE DATA SHEETS FOR DETAILS

GENERAL-PURPOSE STEAM TURBINE
DATA SHEET
SI UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
 BY ______

ENGINEERING REQUIREMENTS

○ SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES (4.8.1.7)
○ CALCS AND/OR DATA FOR SEPARATION MARGIN (4.8.2.2)
○ TRAIN TORSIONAL VIBRATION ANALYSIS (4.8.3.5)
○ WEIGHT OF HALF KEYS (4.8.4.2)
○ RESIDUAL UNBALANCE CHECK (4.8.4.3)

REMARKS: ______

INSPECTION REQUIREMENTS

○ 100% ULTRASONIC INSPECTION AFTER ROUGH MACHINING (6.2.2.3.1)
○ USE INSPECTOR'S CHECK LIST
CASTING SURFACE INSPECTION (6.2.2.1.1) ○ MSS SP-55
○ OTHER ______
○ WELD INSPECTION (6.2.2.1.2)
SPECIAL NDT INSPECTION (6.2.1.3)

COMPONENT	MAG. PART.	DYE PENET.	RADIO-GRAPHIC	ULTRA-SONIC	OBSE-RVED	WITN.
T&T VALVE					○	○
STM CHEST					○	○
CASING					○	○
PIPING					○	○
ROTOR					○	○
					○	○
					○	○

REMARKS: ______

○ PREPARATION FOR SHIPMENT

TURBINE AUX. EQUIPMENT AND SPARE ROTOR PREPARED FOR (6.4.1):

○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT

REMARKS: ______

TESTS (6.3)	REQ'D.	WITN.	OBSVD. (6.1.5)
HYDROSTATIC (6.3.2.1)	●	○	○
MECH. RUN (6.3.3)	●	○	○
	○	○	○
PERFORMANCE (6.3.4.1)	○	○	○
COMPLETE UNIT (6.3.4.2)	○	○	○
GEAR (6.3.4.3)	○	○	○
SOUND LEVEL (6.3.4.4)	○	○	○
AUX. EQUIPMENT (6.3.4.5)	○	○	○
______	○	○	○
______	○	○	○

REMARKS: ______

WEIGHTS

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

REMARKS: ______

GENERAL-PURPOSE STEAM TURBINE
DATA SHEET
U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______
SPECIFICATION NO. ______
REVISION NO. ______ DATE ______
PAGE 1 OF 3 BY ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

FOR ______ UNIT ______
SITE ______ NO. REQUIRED ______
SERVICE ______ DRIVEN EQUIPMENT ______
MANUFACTURER ______ MODEL ______ SERIAL NO. ______

NOTE: ○ INDICATES INFORMATION COMPLETED BY PURCHASER ☐ BY MANUFACTURER ◙ BY MFGR IF NOT BY PURCHASER

○ OPERATING CONDITIONS

OPERATING POINT	POWER, BHP	SPEED, RPM
NORMAL		
RATED		
OTHER (4.1.4)		

○ DUTY, SITE AND UTILITY DATA

APPLICATION IS (SPARED, UNSPARED) ______

○ WIDE SPEED RANGE ○ RAPID START
○ SLOW ROLL REQ. (4.10.4) ○ HAND VALVES REQ. (5.4.1.5)
DUTY ○ CONTINUOUS ○ STANDBY
○ UNATTENDED AUTO START (4.1.6)
LOCATION (4.1.14) ○ INDOOR ○ HEATED ○ UNHEATED
○ OUTDOOR ○ ROOF ○ W/O ROOF
AMBIENT TEMP., °F: MIN. ______ MAX ______
UNUSUAL CONDITIONS (4.1.14) ○ DUST ○ SALT ATMOSPHERE
○ OTHER ______
ELECT. AREA (4.1.13) CLASS ______ GROUP ______ DIV ______
○ NON-HAZARDOUS
CONTROL POWER V ______ PH. ______ HZ ______
AUX. MOTORS V ______ PH. ______ HZ ______
COOLING WATER: PRESS, PSIG ______ Δ P, PSI ______
FLOW, GPM ______ Δ T, °F: ______
ALLOW. SOUND PRESS LEVEL (4.1.12) ______ dBA @ ______ FT

○ STEAM CONDITIONS

	MAX	NORMAL	MIN.
INLET PRESS, PSIG			
INLET TEMP,°F			
EXHAUST PRESS (PSIG) (IN. HGA)			
○ STEAM CONTAMINANTS (4.11.1.7)			

TURBINE DATA

☐ ALLOW SPEEDS, RPM, MAX ______ MIN ______
☐ MAX CONT SPEED, RPM (3.1.10) ______
☐ TRIP SPEED, RPM ______ BLADE TIP VEL, FPS ______
☐ FIRST CRITICAL SPEED, RPM (4.8.2.1) ______
☐ EXH. TEMP °F ______ NORMAL ______ NO LOAD
☐ POTENTIAL MAX POWER, BHP (3.1.20) ______
☐ MAX. NOZZLE STEAM FLOW, LBS/HR ______
ROTATION FACING GOVERNOR END ○ CCW ○ CW
○ DRIVEN EQUIPMENT THRUST, LBS (4.9.11) ______
(VERTICAL TURBINE) (4.9.3)
○ WATER PIPING FURN. BY ○ VENDOR ○ OTHERS
○ OIL PIPING FURN. BY ○ VENDOR ○ OTHERS

☐ PERFORMANCE

OPERATING POINT/ STEAM CONDITION	NO. HAND VALVES OPEN (5.4.1.5)	STEAM RATE, LBS/HP-HR
NORMAL/NORMAL (CERTIFIED SR)		
RATED/NORMAL		
(1) MIN. INLET - MAX EXHAUST		

(1) ○ RATED ○ ______% RATED ○ NORMAL (4.1.4)

APPLICABLE SPECIFICATION

API-611 OTHER ______

CONSTRUCTION

TURBINE TYPE ○ HORIZ ○ VERTICAL
NO STAGES ______ WHEEL DIA., IN. ______
ROTOR: ☐ BUILT UP ☐ SOLID ☐ OVERHUNG
☐ BETWEEN BRGS
BLADING ☐ 2 ROW ☐ 3 ROW ☐ RE-ENTRY
CASING SPLIT ☐ AXIAL ☐ RADIAL
CASING SUPPORT ☐ CENTERLINE ☐ FOOT
○ VERT. JACKSCREWS (4.2.13)
VERTICAL TURBINE FLANGE
○ NEMA "P" BASE ○ OTHER (4.4.9) ______
TRIP VALVE ☐ INTEGRAL ☐ SEPARATE
INTERSTAGE SEALS ☐ LABYRINTH ☐ CARBON
END SEALS ☐ CARBON RING, NO/BOX ______
☐ LABYRINTH ☐ MATERIAL ______
☐ MECHANICAL ☐ MFR ______
TYPE RADIAL BEARINGS (4.9.1) ______
TYPE THRUST BEARING (4.9.2) ______
☐ CALCULATED THRUST LOAD ______ PSI (4.9.15)
☐ BEARING MFGR's ULTIMATE RATING ______ PSI
THRUST COLLAR (4.9.10.2) ☐ REPLACEABLE ☐ INTEGRAL ☐ NONE
◙ LUBE OIL VISCOSITY (4.10.3) ISO GRADE ______
LUBRICATION ○ RING OILED ○ PRESSURE ○ GREASE
OIL MIST (4.9.19)
○ PURGE OIL MIST ○ PURE OIL MIST
○ BEARING HOUSING OILER TYPE ______

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

GENERAL-PURPOSE STEAM TURBINE DATA SHEET U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
 BY ______

MATERIALS

HIGH PRESSURE CASING ______ GRADE ______
EXHAUST CASING ______ GRADE ______
NOZZLES ______ GRADE ______
BLADING ______ GRADE ______
WHEELS ______ GRADE ______
SHAFT ______ GRADE ______
SHAFT COATING UNDER PACKING (4.6.2.3)
MATERIAL ______
APPLICATION METHOD ______
THICKNESS ______
GOV. VALVE TRIM ______
INLET STRAINER ______ MESH SIZE ______
COUPLING SPACER/HUBS ______
COUPLING DIAPHRAGMS (DISKS) ______

STEAM CONTROL

SPEED CHANGER — MANUAL — PNEUM. — ELECT (5.4.2.3)
MFR. ______ MODEL ______

CONTROLLED VARIABLE	OPERATING RANGE		CONTROL SIGNAL	
SPEED	___ TO ___	RPM	___ TO ___	PSIG/mA
	___ TO ___	RPM	___ TO ___	PSIG/mA

CONNECTIONS (4.4.1)

	SIZE	RAT'G	FAC'G	POS.	MATING PARTS FURNISHED (4.4.6.5)
INLET					
EXHAUST					
DRAINS					

COUPLINGS (5.2) — SEE SEPARATE DATA SHEET

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

TURBINE VENDOR MOUNTS HALF COUPLING

DYN. BALANCE CL (5.2.8)
AGMA CLASS 8 — OTHER ______
TURBINE SHAFT — TAPER — STRA'T — HYDRAULIC FIT HUB

MOUNTING PLATES

TYPE: (5.3.1.1) — BASEPLATE — SOLEPLATE
FURN. BY: — TURBINE VENDOR
DRIVEN EQUIPMENT VENDOR — OTHER ______
EQUIPMENT TO BE MOUNTED: (5.3.2.1)
TURBINE — GENERATOR — GEAR
PUMP — OTHER ______
UNGROUTED BASEPLATE (5.3.2.4)
SUITABLE FOR COLUMN MOUNTING
TURBINE VENDOR FURNISHES SUBPLATES

ACCESSORY EQUIPMENT BY VENDOR

REMOTE TRIP — SOLENOID
VACUUM BREAKER (5.4.2.9)
AUTOMATIC STEAM SEALING SYSTEM (4.7.5)
GLAND VACUUM DEVICE WITH: (4.7.4)
WATER EDUCTOR — STEAM EJECTOR
SENTINEL WARNING VALVE (5.4.5.2)
INSULATION, TYPE: ______
TACHOMETER (5.4.4.1), TYPE ______
MFR. ______ MODEL ______
MOUNTED BY ______
THERMAL RELIEF VALVES (5.4.4.7.3)
SHUTOFF VALVES FOR SHUTDOWN SENSORS
LOCAL GAUGE BOARD WITH FOLLOWING PRESSURE GAUGES: (5.4.3.1)
THROTTLE STEAM — FIRST STAGE
NOZZLE RING — EXHAUST
LIQUID FILLED GAUGES (5.4.4.4)
INSTRUMENT PANEL (5.4.3.2.1)
BASEMOUNT
FREE STANDING

EXTERNAL LUBE OIL SYSTEM

CIRCULATING (4.10.5) — PRESSURE (4.10.6)
VENDOR FURNISH SYSTEM FOR: — TURBINE
OTHER ______
OIL SYSTEM TO BE: — CONSOLE TYPE
MOUNTED ON BASEPLATE
OIL SYSTEM TO INCLUDE FOLLOWING EQUIPMENT: (4.10.5)(4.10.7)
STANDBY OIL PUMP: TYPE DRIVER ______
LOW OIL PRESS ALARM SWITCH
LOW OIL PRESS TRIP SWITCH
HEATER (4.10.8) — ELECTRIC — STEAM
OIL DRAIN SIGHT FLOW INDICATORS
HAND OPERATED STANDBY PUMP

VIBRATION AND POSITION DETECTORS (5.4.6)

FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING VIBRATION PROBES (4.9.32)
FURN. AXIAL POSITION PROBES — NO. OF PROBES ______
MFR. ______ MODEL ______
FURN. RADIAL PROBES — NO. OF PROBES PER BEARING ______
MFR. ______ MODEL ______
FURNISH BEARING METAL TEMP SENSORS FOR:
RADIAL BEARINGS — THRUST BEARINGS
TURBINE VENDOR SUPPLIES AND CALIBRATES MONITORS FOR:
AXIAL AND RADIAL PROBES
BEARING TEMPERATURE SENSORS
SEE SEPARATE DATA SHEETS FOR DETAILS

GENERAL-PURPOSE STEAM TURBINE
DATA SHEET
U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______

REVISION NO. ______ DATE ______

PAGE 3 OF 3 BY ______

ENGINEERING REQUIREMENTS

○ SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES (4.8.1.7)

○ CALCS AND/OR DATA FOR SEPARATION MARGIN (4.8.2.2)

○ TRAIN TORSIONAL VIBRATION ANALYSIS (4.8.3.5)

○ WEIGHT OF HALF KEYS (4.8.4.2)

○ RESIDUAL UNBALANCE CHECK (4.8.4.3)

REMARKS: ______

INSPECTION REQUIREMENTS

○ 100% ULTRASONIC INSPECTION AFTER ROUGH MACHINING (6.2.2.3.1)

○ USE INSPECTOR'S CHECK LIST

CASTING SURFACE INSPECTION (6.2.2.1.1) ○ MSS SP-55 ○ OTHER ______

○ WELD INSPECTION (6.2.2.1.2)

○ SPECIAL NDT INSPECTION (6.2.1.3)

COMPONENT	MAG. PART.	DYE PENET.	RADIO-GRAPHIC	ULTRA-SONIC	OBSE-RVED	WITN-
T&T VALVE					○	○
STM CHEST					○	○
CASING					○	○
PIPING					○	○
ROTOR					○	○
					○	○
					○	○

REMARKS: ______

○ PREPARATION FOR SHIPMENT

TURBINE AUX. EQUIPMENT AND SPARE ROTOR PREPARED FOR (6.4.1):

○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT

REMARKS: ______

TESTS (6.3)	REQ'D.	WITN.	OBSVD. (6.1.5)
HYDROSTATIC (6.3.2.1)	●	○	○
MECH. RUN (6.3.3)	●	○	○
	○	○	○
PERFORMANCE (6.3.4.1)	○	○	○
COMPLETE UNIT (6.3.4.2)	○	○	○
GEAR (6.3.4.3)	○	○	○
SOUND LEVEL (6.3.4.4)	○	○	○
AUX. EQUIPMENT (6.3.4.5)	○	○	○
______	○	○	○
______	○	○	○

REMARKS: ______

WEIGHTS

☐ TURBINE ______ LB

☐ ROTOR ______ LB

☐ TURBINE UPPER HALF CASING ______ LB

☐ MAX MAINTENANCE (IDENTIFY) ______ LB

☐ T & T VALVE ______ LB

☐ BASEPLATE ______ LB

☐ MISC. ______ LB

☐ TOTAL SHIPPING WEIGHT ______ LB

REMARKS: ______

APPENDIX B—DAMPED UNBALANCED RESPONSE ANALYSIS

B.1 Lateral Analysis

B.1.1 The damped unbalanced response analysis shall include but shall not be limited to the following considerations:

a. Support (base, frame, and bearing-housing) stiffness, mass, and damping characteristics, including the effects of rotational speed variation. The vendor shall state the assumed support-system values and the basis for these values (for example, tests of identical rotor support systems, assumed values).

b. Bearing lubricant-film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances, and maximum to minimum clearances.

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

d. Rotor masses, including the mass moment of coupling halves, stiffness, and damping effects (for example, accumulated fit tolerances, fluid stiffening and damping, and frame and casing effects).

e. Asymmetrical loading (for example, partial arc admission, gear forces, side steams, and eccentric clearances).

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

For machines equipped with antifriction bearings, the vendor shall state the bearing stiffness and damping values used for the analysis and either the basis for these values or the assumptions made in calculating the values.

● **B.1.2** When specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (that is, a train lateral analysis shall be performed).

Note: This analysis should be considered for machinery trains with coupling spacers greater than 1 meter (36 inches), rigid couplings, or both.

B.1.3 As a minimum, the damped unbalanced response analysis shall include the following:

a. A plot and identification of the mode shape at each resonant speed (critically damped or not) from zero to trip, as well as the next mode occurring above the trip speed.

b. Frequency, phase, and response amplitude data (Bode plots) at the vibration probe locations through the range of each critical speed, using the following arrangement of unbalance for the particular mode. This unbalance shall be sufficient to raise the displacement of the rotor at the probe locations to the vibration limit defined by the following equation:

$$Lv = 25.4\sqrt{\frac{12{,}000}{N}} \qquad \text{(B-1)}$$

In U.S. Customary units:

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

Where:

Lv = vibration limit (amplitude of unfiltered vibration), in micrometers (mils) peak to peak.

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

This unbalance shall be no less than two times the unbalance defined by the following equation:

$$U = 6350W/N \qquad \text{(B-2)}$$

In U.S. Customary units:

$$U = 4W/N$$

Where:

U = input unbalance from the rotor dynamic response analysis, in gram-millimeters (ounce-inches).

W = journal static weight load, in kilograms (pounds), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung weight load (that is, the weight outboard of the bearing), in kilograms (pounds).

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

The unbalance weight or weights shall be placed at the locations within the bearing span that have been analytically determined to affect the particular mode most adversely. For translatory modes, the unbalance shall be based on both journal static weights and shall be applied at the locations of maximum displacement. For conical modes, each unbalance shall be based on the journal weight and shall be applied at the location of maximum displacement of the mode nearest the journal used for the unbalance calculation, 180 degrees out of phase. Figure B-1 shows the typical mode shapes and indicates the location and definition of U for each of the shapes.

c. Modal diagrams for each response in Item b above, indicating the phase and major-axis amplitude at each coupling engagement plane, the centerlines of the bearings, the locations of the vibration probes, and each seal area throughout the machine. The minimum design diametral running clearance of the seals shall also be indicated.

d. A verification test of the rotor unbalance, to establish the validity of the analytical model, a verification test of the rotor unbalance is required at the completion of the mechanical running test. Therefore, additional plots based on the actual unbalance to be used during this test shall be provided as follows: for machines that meet the requirements of B.1.3, Item b, and B.1.4, additional Bode plots, as specified in B.1.3, Item b, shall be provided. The location of the test unbalance shall be determined by the vendor. The amount of unbalance shall be sufficient to raise the vibration levels, as measured at the vibration probes, to those specified in B.1.3, Item b. In all cases the unbalance plots shall include the effects of any test-stand conditions (including the effects of test seals) that may be used during the verification test of the rotor unbalance (see B.2).

e. Unless otherwise specified, a stiffness map of the undamped rotor response from which the damped unbalance response analysis specified in Item c above was derived. This plot shall show frequency versus support-system stiffness, with the calculated support-system stiffness curves superimposed.

f. For machines whose bearing support system stiffness values are less than or equal to 3.5 times the bearing stiffness values, the calculated frequency-dependent support stiffness and damping values (impedances) or the values derived from modal testing. The results of the damped unbalanced response analysis shall include Bode plots that compare absolute shaft motion with shaft motion relative to the bearing housing.

B.1.4 The damped unbalanced response analysis shall indicate that the machine in the unbalanced condition described in B.1.3, Item b, will meet the following acceptance criteria (see Figure 1):

a. If the amplification factor is less than 2.5, the response is considered critically damped and no separation margin is required.

b. If the amplification factor is between 2.5 and 3.55, a separation margin of 15 percent above the maximum continuous speed and 5 percent below the minimum operating speed is required.

c. If the amplification factor is greater than 3.55 and the critical response peak is below the minimum operating speed, the required separation margin (a percentage of minimum speed) is equal to the following:

$$SM = 100 - (84 + 6/(AF - 3)) \quad \text{(B-3)}$$

d. If the amplification factor is greater than 3.55 and the critical response peak is above the trip speed, the required separa-

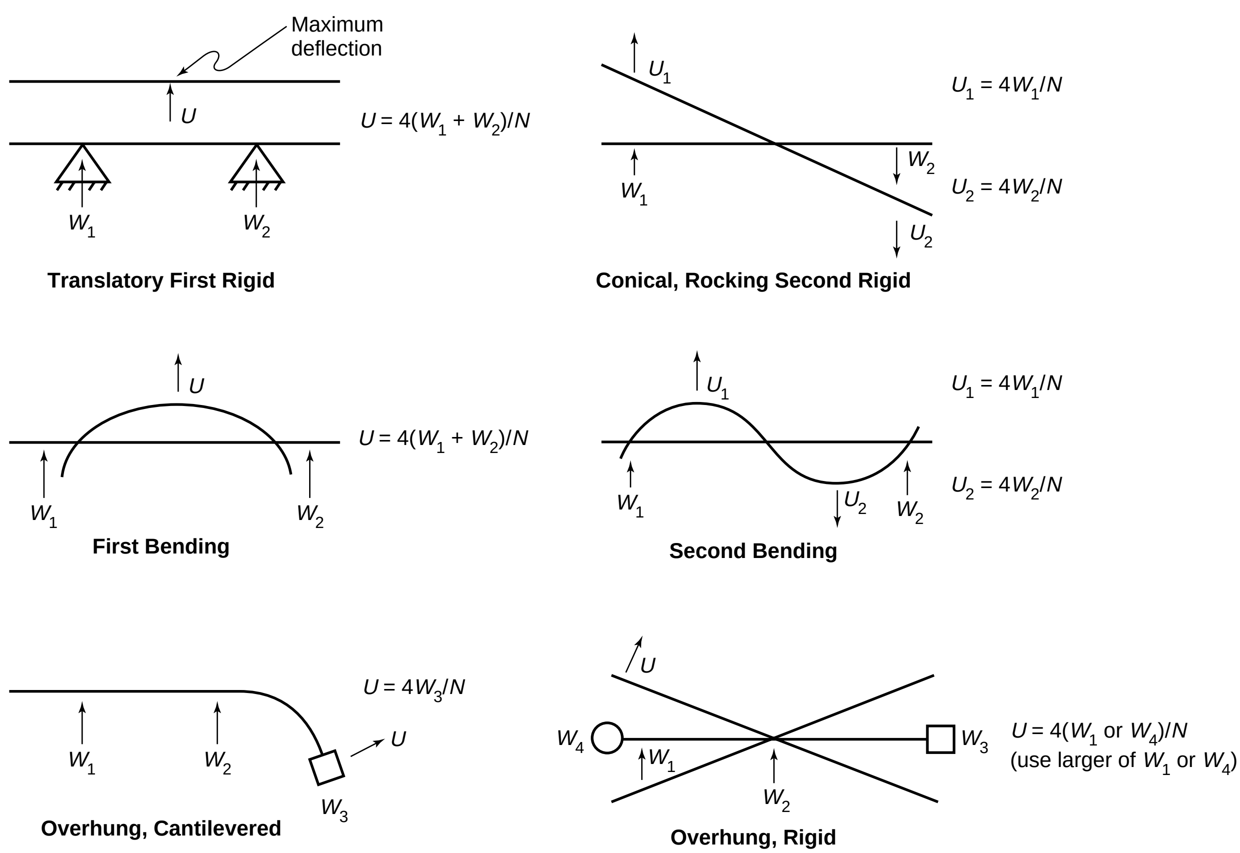


Figure B-1—Typical Mode Shapes

tion margin (a percentage of maximum continuous speed) is equal to the following:

$$SM = (126–(6/(AF–3))) – 100 \tag{B-4}$$

B.1.5 The calculated unbalanced peak-to-peak rotor amplitudes (see B.1.3, Item b) at any speed from zero to trip shall not exceed 75 percent of the minimum design diametral running clearances throughout one machine (with the exception of floating-ring seal locations).

B.1.6 If, after the purchaser and the vendor have agreed that all practical design efforts have been exhausted, the analysis indicates that the separation margins still cannot be met or that a critical response peak falls within the operating speed range, acceptable amplitudes shall be mutually agreed upon by the purchaser and the vendor, subject to the requirements of B.1.5.

B.1 Shop Verification of Unbalanced Response Analysis

B.1.1 A demonstration of rotor response at future unbalanced conditions is necessary because a well-balanced rotor may not be representative of future operating conditions (see B.1.d). This test shall be performed as part of the mechanical running test (see 4.3.3), and the results shall be used to verify the analytical model. Unless otherwise specified, the verification test of the rotor unbalance shall be performed only on the first rotor (normally the spare rotor, if two rotors are purchased). The actual response of the rotor on the test stand to the same unbalance weight as was used to develop the Bode plots specified in B.1.3 shall be the criterion for determining the validity of the damped unbalanced response analysis. To accomplish this, the following procedure shall be followed:

a. During the mechanical running test (see 4.3.3), the amplitudes and phase angle of the indicated vibration at the speed nearest the critical or criticals of concern shall be determined.

b. A trail weight, not more than one-half the amount calculated in B.1.3, Item b, shall be added to the rotor at the location specified in B.1.3, Item d; 90 degrees away from the phase of the indicated vibration at the speed or speeds closest to the critical or criticals of concern.

c. The machine shall then be brought up to the operating speed nearest the critical of concern, and the indicated vibration amplitudes and phase shall be measured. The results of this test and the corresponding indicated vibration data from Item a above shall be vectorially added to determine the magnitude and phase location of the final test weight required to produce the required test vibration amplitudes.

d. The final test weight described in Item c above shall be added to the rotor, and the machine shall be brought up to the operating speed nearest the critical of concern. When more than one critical of concern exists, additional test runs shall be performed for each, using the highest speed for the initial test run.

Note: It is recognized that the dynamic response of the machine on the test stand will be a function of the agreed-upon test conditions and that unless the test-stand results are obtained at the conditions of pressure, temperature, speed, and load expected in the field, they may not be the same as the results expected in the field.

B.1.2 The parameters to be measured during the test shall be speed and shaft synchronous (1×) vibration amplitudes with corresponding phase. The vibration amplitudes and phase from each pair of x-y vibration probes shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major-axis amplitudes of each response peak shall not exceed the limits specified in B.1.5. (More than one application of the unbalance weight and test run may be required to satisfy these criteria.)

The gain of the recording instruments used shall be predetermined and preset before the test so that the highest response peak is within 60-100 percent of the recorder’s full scale on the test-unit coast-down (deceleration; see B.2.4). The major-axis amplitudes at the operating speed nearest the critical or criticals of concern shall not exceed the values predicted in accordance with B.1.3, Item d, before coast-down through the critical of concern.

B.1.2.1 Vectorial addition of slow-roll (300 to 600 revolutions per minute) electrical and mechanical runout is required to determine the actual vibration amplitudes and phase during the verification test. Vectorial addition of the bearing-housing motion is required for machines that have flexible rotor supports (see B.1.3, Item f).

Note 1: The phase on each vibration signal, x or y, is the angular measure, in degrees, of the phase difference (lag) between a phase reference signal (from a phase transducer sensing a once-per-revolution mark on the rotor, as described in API Standard 670) and the next positive peak, in time, of the synchronous (1×) vibration signal. (A phase change will occur through a critical or if a change in a rotor’s balance condition occurs because of shifting or looseness in the assembly.)
Note 2: The major-axis amplitude is properly determined from a lissajous (orbit) display on an oscilloscope or equivalent instrument. When the phase angle between the x and y signals is not 90 degrees, the major-axis amplitude can be approximated by $(x^2 + y^2)^{0.5}$. When the phase angle between the x and y signals is 90 degrees, the major-axis value is the greater of the two vibration signals.

B.1.2.2 The results of the verification test shall be compared with those from the original analytical model. The vendor shall correct the model if it fails to meet any of the following criteria:

a. The actual critical speeds shall not deviate from the predicted speeds by more than ±5 percent.

b. The predicted amplification factors shall not deviate from the actual test-stand values by more than ±20 percent.

c. The actual response peak amplitudes, including those that are critically damped, shall be within ±50 percent of the predicted amplitudes.

B.1.3 Additional testing will be required if, from the test data described above or damped, corrected unbalance response analysis (see B.2.2.2), it appears that either of the following conditions exists:

a. Any critical response will fail to meet the separation margin requirements (B.1.4) or will fall within the operating speed range.

b. The requirements of B.1.5 have not been met.

B.1.4 Rotors requiring additional testing per B.2.3 shall receive additional testing as follows: Unbalance weights shall be placed as described in B.1.3, Item b; this may require disassembly of the machine for placement of the unbalance weights. Unbalance magnitudes shall be achieved by adjusting the indicated unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by Equation B-1 (see B.1.3, Item b) at the maximum continuous speed; however, the unbalance shall be no less than twice the unbalance limit specified in 2.8.4.2. The measurements from this test, taken in accordance with B.2.2, shall meet the following criteria:

a. At no speed within the operating speed range, including the separation margins, shall the shaft deflections exceed 55 percent of the minimum design running clearances or 150 percent of the allowable vibration limit at the probes (see B.1.3, Item b, and Figure 1).

b. At no speed outside the operating speed range, including the separation margins, shall shaft deflections exceed 90 percent of the minimum design running clearances (see B.1.3).

The internal deflection limits specified in Items a and b above shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in B.1.3, Item c. Actual internal displacements for these tests shall be calculated by multiplying these ratios by the peak readings from the probes. Acceptance will be based on these calculated displacements or inspection of 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.

APPENDIX C—WORKSHEET AND PROCEDURE FOR DETERMINATION OF RESIDUAL UNBALANCE

C.1 Scope

This appendix describes 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.1 Definition

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, residual unbalance shall be expressed in gm-mm (gram-millimeters) or oz.-in. (ounce-inches).

C.1 Maximum Allowable Residual Unbalance

C.1.1 The maximum allowable residual unbalance per plane shall be calculated using Equation 1 in 4.8.4.2 of this standard.

C.1.2 If the actual static weight load on each journal is not known, assume that the total rotor weight is equally supported by the bearings. For example, a two-bearing rotor weighing 3,000 kilograms (6,600 pounds) would be assumed to impose a static weight load of 1,500 kilograms (3,300 pounds) on each journal.

C.1 Residual Unbalance Check

C.1.1 GENERAL

C.1.1.1 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.1.1.2 To check the residual unbalance, a known trial weight is attached to the rotor sequentially in six (or twelve, if specified by the purchaser) equally spaced radial positions, each at the same radius. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in C.4.2.

C.1.2 PROCEDURE

C.1.2.1 Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual unbalance [that is, if U_{max} is 1,440 gm-mm (2 oz.-in.), the trial weight should cause 1,440 to 2,880 gm-mm (2 to 4 oz.-in.) of unbalance].

C.1.2.2 Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (six or twelve) in equal (60 or 30 degree) increments around the rotor. Add the trial weight 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 weight to any one of the marked radial positions.

C.1.2.3 To verify that an appropriate trial weight has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial weight should be used. If little or no meter reading results, a larger trial weight should be used. Little or no meter reading generally indicates that the rotor was not balanced correctly, the balancing machine is not sensitive enough, or a balancing machine fault exists (i.e., a faulty pickup). Whatever the error, it must be corrected before proceeding with the residual unbalance check.

C.1.2.4 Locate the weight 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.1.2.5 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 weight is added at the rotor's heavy spot; the minimum reading occurs when the trial weight 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 weight. The distance of the circle's center from the origin of the polar plot represents the residual unbalance in that plane.

C.1.2.6 Repeat the steps described in C.4.2.1 through 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 in any balance plane, the residual unbalance check shall be repeated in all planes.

C.1.2.7 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: __________ rpm

N—Maximum Allowable Rotor Speed: __________ rpm

W—Weight of Journal (closet to this correction plane): __________ kg (lbs)

U_{max}—Maximum Allowable Residual Unbalance =
6350 *W/N* (4 *W/N*)
6350 × ______ kg/______ rpm; 4 × ______lbs/______rpm __________ gm-mm (oz.-in.)

Trial unbalance (2 × U_{max}) __________ gm-mm (oz.-in.)

R—Radius (at which weight will be placed): __________ mm (in.)

Trial Unbalance Weight = Trial Unbalance/*R*
_____gm-mm/_____mm/______oz.-in./______inches __________ g (oz.)

Conversion Information: 1 ounce = 28.350 grams

Test Data

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1	0°	
2	60°	
3	120°	
4	180°	
5	240°	
6	300°	
Repeat 1	0°	

Rotor Sketch

Test Data—Graphic Analysis

Step 1: Plot data on the polar chart (Figure C-1 continued). Scale the chart so the largest and smallest amplitude will fit conveniently.

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

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

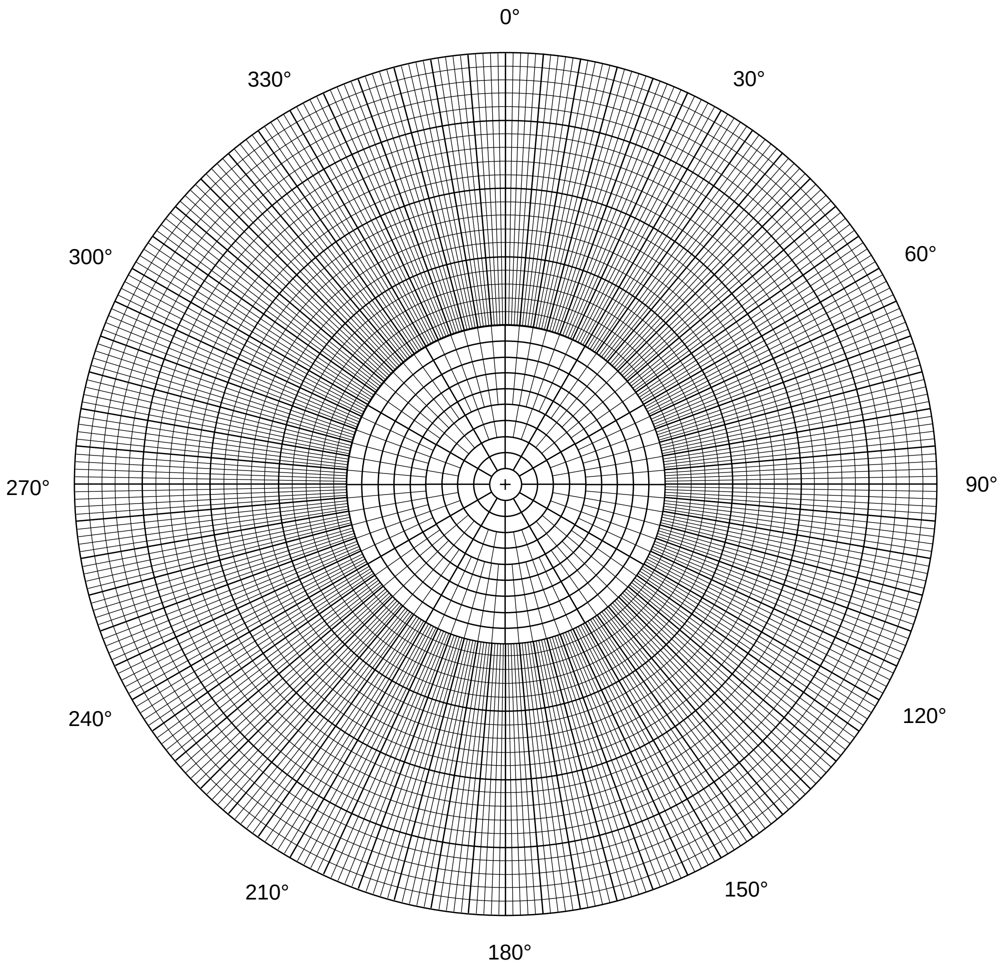
Step 4: Record the trial unbalance from above. __________ gm-mm (oz.-in.)

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

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

You now have a correlation between the units on the polar chart and the gm-in. of actual balance.

Figure C-1—Residual Unbalance Work Sheet



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

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

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

Record actual residual unbalance ____________________________ (gm-mm)(oz.-in.)

Record allowable residual unbalance (from Figure C-1) ______________ (gm-mm)(oz.-in.)

Correction plane ________________ for Rotor No. ____________ (has/has not) passed.

By ____________________________ Date ______________________________

Figure C-1—Residual Unbalance Work Sheet (continued)

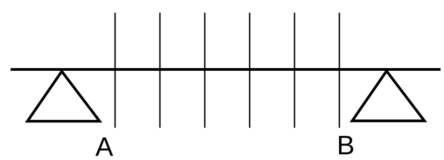
Equipment (Rotor) No.:	*C–101*	
Purchase Order No.:	______	
Correction Plane (inlet, drive-end, etc.—use sketch):	*A*	
Balancing Speed:	*800*	rpm
N—Maximum Allowable Rotor Speed:	*10,000*	rpm
W—Weight of Journal (closet to this correction plane):	*908*	~~kg~~ (lbs)
U_{max}—Maximum Allowable Residual Unbalance = 6350 *W/N* (4 *W/N*) ~~6350 × _____ kg/_____ rpm~~; 4 × *908* lbs/ *10,000* rpm	*0.36*	~~gm-mm~~ (oz.-in.)
Trial unbalance (2 × U_{max})	*0.72*	~~gm-mm~~ (oz.-in.)
R—Radius (at which weight will be placed):	*6.875*	~~mm~~ (in.)
Trial Unbalance Weight = Trial Unbalance/*R* ~~_____ gm-mm/_____ mm~~/ *0.72* oz.-in./ *6.875* inches	*0.10*	~~g~~ (oz.)

Conversion Information: 1 ounce = 28.350 grams

Test Data

Position	Trial Weight 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°*	*14.0*

Rotor Sketch



C-101

Test Data—Graphic Analysis

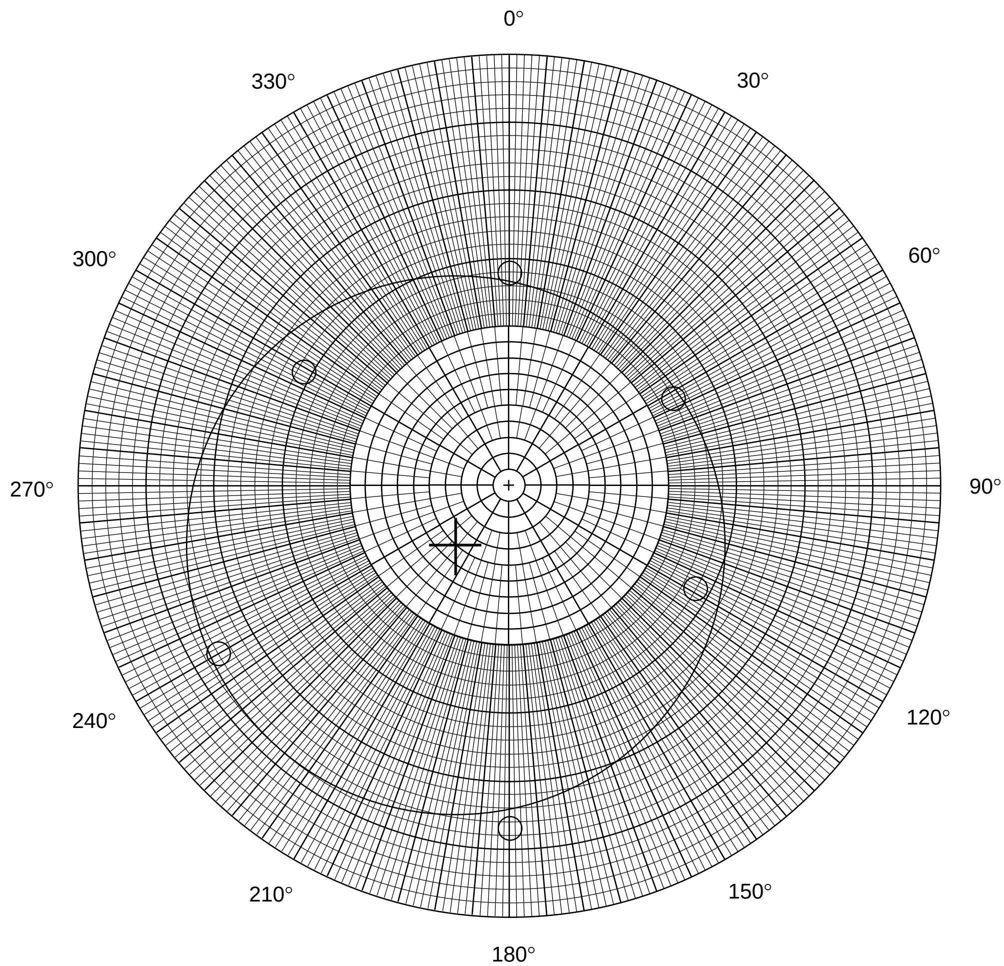
Step 1: Plot data on the polar chart (Figure C-2 continued). Scale the chart so the largest and smallest amplitude will fit conveniently.

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

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record.	*35*	units
Step 4: Record the trial unbalance from above.	*0.72*	~~gm-mm~~ (oz.-in.)
Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).	*1.44*	~~gm-mm~~ (oz.-in.)
Step 6: Divide the answer in Step 5 by the answer in Step 3.	*0.041*	Scale Factor

You now have a correlation between the units on the polar chart and the gm-in. of 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 include: operator error during balancing, a faulty balancing machine pickup or cable, or the balancing machine is not sensitive enough.

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

Record actual residual unbalance *5 (0.041) = 0.21* (~~gm-mm~~)(oz.-in.)

Record allowable residual unbalance (from Figure 22) *0.36* (~~gm-mm~~)(oz.-in.)

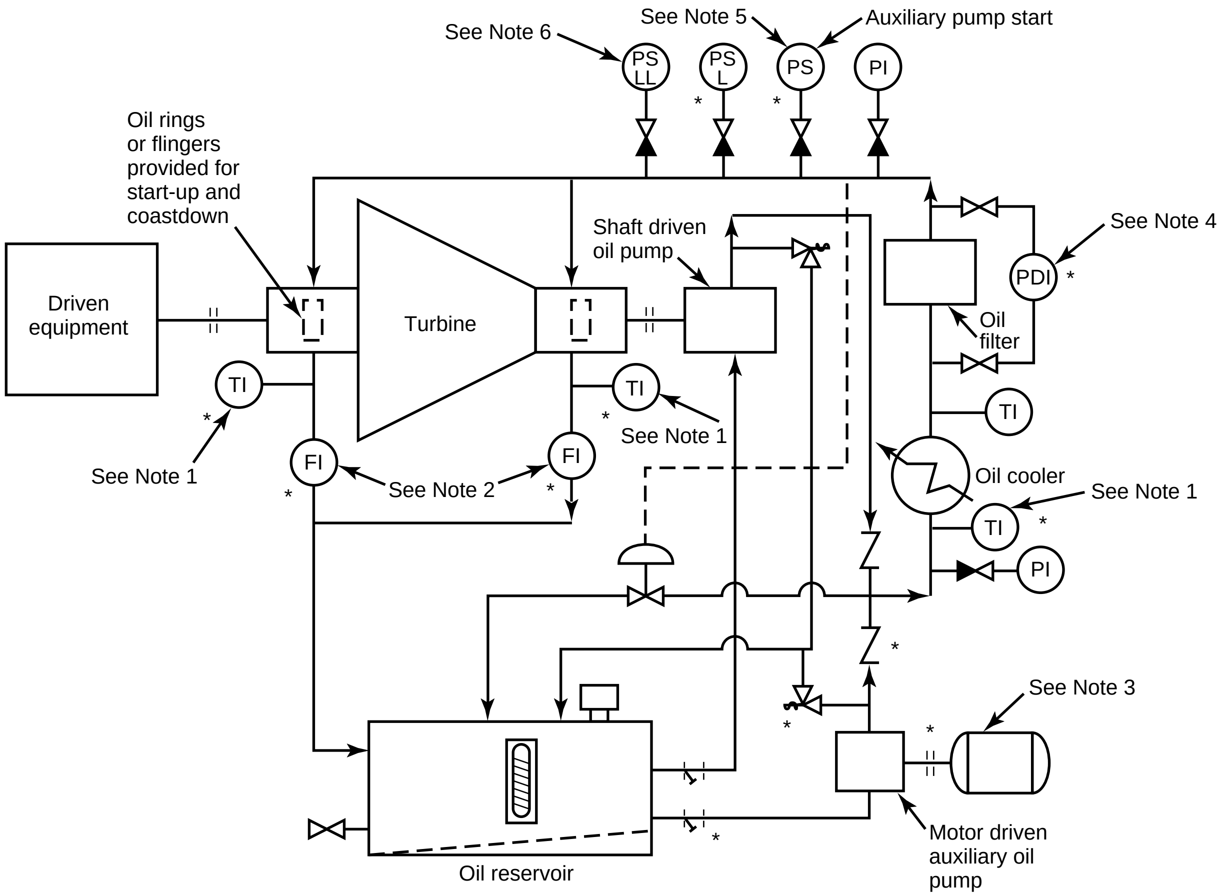
Correction plane *A* for Rotor No. *C-101* (has/~~has not~~) passed.

By *John Inspector* Date *11-31-94*

Figure C-2—Sample Calculations for Residual Unbalance (continued)

APPENDIX D—MINIMUM PRESSURIZED LUBE-OIL SYSTEM

This figure shows a typical schematic for a pressurized lube-oil system. Items with an asterisk (*) represent optional enhancements. All other equipment/instruments are considered to be minimum requirements for such systems. The figure does not constitute any specific design, nor does it include all required details, e.g., vents, drains, etc.



Abbreviations

FI	Flow indicator
TI	Temperature indicator
PI	Pressure indicator
PDI	Pressure differential indicator
PS	Pressure Switch
PSL	Low pressure switch (alarm)
PSLL	Low pressure switch (trip)

Symbols

- Instrument (letters indicate function)
- Gate valve
- Relief valve
- Line strainer
- Pressure control valve
- Check valve
- Block-and-bleed valve

Notes:

1. Option D-1a: The purchaser may specify temperature indicators in the oil drain lines and/or upstream of the oil cooler.
2. Option D-1b: The purchaser may specify flow indicators in the oil drain lines.
3. Option D-1c: The purchaser may specify a motor driven auxiliary oil pump system, including pump, driver, relief valve, check valve, and block valves.
4. Option D-1d: The purchaser may specify a differential pressure indicator.
5. Option D-1e: The purchaser may specify an auxiliary oil pump start switch if Option D-1c has been specified.
6. If the turbine is fitted with another more reliable low oil pressure shutdown device, this switch may also be considered optional.

Figure D-1—Minimum Pressurized Lube-Oil System (With Optional Enhancements)

APPENDIX E—VENDOR DRAWING AND DATA REQUIREMENTS

GENERAL-PURPOSE STEAM TURBINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______ DATE ______
REQUISITION NO. ______ DATE ______
INQUIRY NO. ______ DATE ______
PAGE 1 OF 2 BY ______

FOR ______
SITE ______
SERVICE ______

REVISION ______
UNIT ______
NO. REQUIRED ______

Proposal — Bidder shall furnish ______ copies of data for all items indicated by an X.

Review — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.

Final — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

DISTRIBUTION RECORD

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

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

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

GENERAL-PURPOSE STEAM TURBINE VENDOR DRAWING AND DATA REQUIREMENTS

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

Proposal Bidder shall furnish ________ copies of data for all items indicated by an X.

Review Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.

Final Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.
Vendor shall furnish ________ operating and maintenance manuals.

DISTRIBUTION RECORD

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

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

Notes:

1. The vendor shall proceed with manufacture upon receipt of the order. The vendor may proceed with manufacture without the purchaser's approval of the drawings when necessary to meet the scheduled shipping date.
2. Send all drawings and data to ____________________
3. All drawings and data must show project, appropriation, purchase order, and item numbers, as well as plant location and unit. In addition to the copies specified above, one set of the drawings and instructions necessary for field installation must be forwarded with the shipment.
4. See the description of required items below.

Nomenclature:

___ S weeks prior to shipment
___ F weeks after firm order
___ D weeks after receipt of approved drawings

Vendor ____________________
Date ____________ Vendor Reference ____________________
Signature ____________________
(Signature acknowledges receipt of all instructions)

Description

1. Certified dimensional outline drawing including the following:
   a. Size, rating, and location of all customer connections, with allowable flange loading for inlet and exhaust steam connections.
   b. Approximate overall handling weights.
   c. Overall dimensions.
   d. Shaft centerline height and dimensioned shaft end for coupling mounting.
   e. Dimensions of baseplates (if furnished), complete with diameter, number, and locations of bolt holes and the thickness of the metal through which bolts must pass.
   f. The location of the center of gravity.

2. Cross-sectional drawings and bill of materials including the following:
   a. Journal-bearing clearances and tolerance.
   b. Rotor float (axial).
   c. Seal clearances (shaft end and internal labyrinth) and tolerance.
   d. Axial position of wheel(s) relative to inlet nozzle or diaphragms and tolerance allowed.
   e. Outside diameters of all wheels at blade tip.

3. Rotor assembly drawing including the following:
   a. Axial position from active thrust-collar face to the following:
      1. Each wheel (inlet side).
      2. Each radial probe.
      3. Each journal-bearing centerline.
      4. One-event-per-revolution mark.
   b. Thrust-collar assembly details including the following:
      1. Collar-to-shaft fit with tolerance.
      2. Axial runout with tolerance.
      3. Required torque for locknut.
      4. Surface finish requirements for collar faces.
      5. Preheat method and temperature requirements for shrunk-on collar installation.

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

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

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

7. Coupling assembly drawing and bill of materials.

8. Gland-sealing and leak-off schematic including the following:
   a. Flows and pressures for steady-state and transient steam and air.
   b. Relief and control valve settings.
   c. Utility requirements (including electrical, water, steam, and air).
   d. Pipe and valve sizes
   e. Instrumentation, safety devices, and control schemes.
   f. Bill of materials.

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

10. Gland-sealing and leak-off component outline and sectional drawings and data including the following:
    a. Gland-condenser fabrication drawing and bill of materials.
    b. Completed data sheet for condenser.
    c. Ejector drawing and performance curves.
    d. Control valves, relief valves, and instrumentation.
    e. Vacuum pump schematic, performance curves, cross section, outline drawing, and utility requirements (if pump is furnished).

11. Lube-oil schematic including the following:
    a. Steady-state and transient oil flows and pressures at each use point.
    b. Control, alarm, and trip settings (pressure and recommended temperatures).
    c. Heat loads at each use point at maximum load.
    d. Utility requirements (including electrical, water, and air).
    e. Pipe and valve sizes.
    f. Instrumentation, safety devices, and control schemes.
    g. Bill of materials.

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

13. Lube-oil component drawings and data including the following:
    a. Pumps and drivers:
        1. Certified dimensional outline drawing.
        2. Cross section and bill of materials.
        3. Mechanical seal drawing and bill of materials.
        4. Performance curves for centrifugal pumps.
        5. Instruction and operating manuals.
        6. Completed data sheets for pumps and drivers.
    b. Coolers, filters, and reservoir:
        1. Fabrication drawings.
        2. Maximum, minimum, and normal liquid levels in reservoir.
        3. Completed data sheets for cooler(s).
    c. Instrumentation:
        1. Controllers.
        2. Switches.
        3. Control valves.
        4. Gauges.

14. Electrical and instrumentation schematics and bill of materials:
    a. Vibration warning and shutdown limits.
    b. Bearing temperature warning and shutdown limits.
    c. Lube-oil temperature warning and shutdown limits.

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

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

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

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

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

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

21. Steam-rate correction factors for Curves 17 through 20, with off-design steam as follows:
    a. Inlet pressure to maximum and minimum values listed on the data sheets in increments and agreed upon at the time of the order.
    b. Inlet temperature to maximum and minimum values listed on the data sheets in increments agreed upon at the time of the order.
    c. Speed (80 to 105 percent, 5-percent increments).
    d. Exhaust pressure to maximum and minimum values listed on the data sheets in increments agreed upon at the time of the order.

22. Vibration analysis data including the following:
    a. Number of blades—each wheel.
    b. Number of vanes—each diaphragm.
    c. Number of nozzles—nozzle block, single valve only.
    d. Campbell diagram for each stage.
    e. Goodman diagram for each stage.
    f. Number of teeth on gear-type coupling (when furnished by the turbine vendor).

23. Lateral critical speed analysis report including the following:
    a. Method used.
    b. Graphic display of bearing and support stiffness and its effect on critical speeds.
    c. Graphic display of rotor response to unbalance (including damping).
    d. Graphic display of overhung moment and its effect on critical speed (including damping).
    e. Journal static loads.
    f. Stiffness and damping coefficients.
    g. Tilting-pad geometry and configuration:
        1. Pad angle.
        2. Pivot clearance.
        3. Pad clearance.
        4. Preload.

24. Coupling alignment diagram, including recommended limits during operation. Note: all shaft-end position changes and support growths from (15°C) 60°F ambient reference.

25. Weld procedures.

26. Hydrostatic test logs.

27. Mechanical running test logs including the following:
    a. Overspeed trip and governor settings.
    b. Vibration, including x-y plot of amplitude and phase angle versus revolutions per minute during start-up and shutdown.
    c. Auxiliary trip settings.
    d. Observed critical speeds (for flexible rotor).

28. Rotor balance logs.

29. Rotor mechanical and electrical runout.

30. As-built data sheets.

31. As-built dimensions (including design tolerances) or data:
    a. Shaft or sleeve diameters at:
        1. Thrust collar (for separate collars).
        2. Each seal component.
        3. Each wheel (for stacked rotors).
        4. Each interstage labyrinth.
        5. Each journal bearing.
    b. Each wheel bore (for stacked rotors) and outside diameter.
    c. Each labyrinth or seal-ring bore.
    d. Thrust-collar bore (for separate collars).
    e. Each journal-bearing inside diameter.
    f. Thrust-bearing concentricity (axial runout).
    g. Metallurgy and heat treatment for the following:
        1. Shaft.
        2. Wheels.
        3. Thrust collar.
        4. Blades (buckets)

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

    Section 1—Installation:
    a. Storage.
    b. Foundation.
    c. Setting equipment, rigging procedures, component weights, and lifting diagram.
    d. Alignment.
    e. Grouting.
    f. Piping recommendations, including allowable flange loads.
    g. Composite outline drawing for driven/driver train, including anchor-bolt locations.
    h. Dismantling clearances.

    Section 2—Operation:
    a. Start-up.
    b. Normal shutdown.
    c. Emergency shutdown.
    d. Operating limits.
    e. Lube-oil recommendations.

    Section 3—Disassembly and reassembly instructions:
    a. Rotor in casing.
    b. Rotor unstacking and restacking procedures.
    c. Journal bearings for tilting-pad bearings, providing “go/no-go” dimensions with tolerances for three-step plug gauges.
    d. Thrust bearing.
    e. Seals.
    f. Thrust collar.
    g. Wheel reblading procedures.

    Section 4—Performance curves:
    a. Steam flow versus horsepower.
    b. Steam flow versus first-stage pressure.
    c. Steam flow versus speed and efficiency.

d. Steam flow versus thrust-bearing load
e. Extraction curves.
f. Steam condition correction factors (prefer nomograph).

Section 5—Vibration data:
a. Vibration analysis data.
b. Lateral critical speed analysis.

Section 6—As-built data:
a. As-built data sheets.
b. As-built dimensions or data.
c. Hydrostatic test logs.
d. Mechanical running test logs.
e. Rotor balance logs.
f. Rotor mechanical and electrical runout at each journal.

Section 7—Drawing and data requirements:
a. Certified dimensional outline drawing and list of connections.
b. Cross-sectional drawing and bill of materials.
c. Rotor drawing and bill of materials.
d. Thrust-bearing assembly drawing and bill of materials.
e. Journal-bearing assembly drawing and bill of materials.
f. Seal component drawing and bill of materials.
g. Lube-oil schematic and bill of materials.
h. Lube-oil arrangement drawing and list of connections.
i. Lube-oil component drawings and data.
j. Electrical and instrumentation schematics and bill of materials.
k. Electrical and instrumentation arrangement drawing and list of connections.
l. Control- and trip-system drawings and data.
m. Trip- and throttle-valve construction drawings

Note: Items 7, 11, 122, 13, 22f and 32 (Section 7, Items g-i) are required only for the turbine manufacturer's scope of supply.

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

APPENDIX F—INSPECTOR'S CHECKLIST

Inspector's Checklist

Item	Standard 611 4th Edition Reference	O Reviewed	O Observed	O Witnessed	INSPECTED BY	STATUS
GENERAL						
Surface and subsurface inspection (optional)	4.2.1.3					
MATERIAL INSPECTION						
Material inspection certification/testing (optional)	4.2.2.1					
Mechanical Inspection						
Casing openings size/finish	2.4.7/2.4.3					
Shaft finishes	2.6.2.1					
Shaft electrical and mechanical run-out (optional)	2.8.4.6/2.6.2.2					
Couplings and guards	3.2					
Rotor balance	2.8.4.2					
Balance machine residual (optional)	2.8.4.3					
Rotation arrow/nameplate data/units	2.12					
Oil system cleanliness (API 614)	2.2.12.4/4.2.3.2					
MECHANICAL RUNNING TEST						
Vibration	2.8.4.5					
Contract shaft seals and bearings	4.3.3.1.1					
Oil flows, P,T as specified (optional)	4.3.3.1.2					
No leaks observed	4.3.3.1.8					
Protective devices operational	4.3.3.1.9					
Bearing inspection after test satisfactory	4.3.3.4.1					
Spare rotor fit and run	4.3.3.4.3					
OPTIONAL TESTS						
Performance	4.3.4.1					
Complete unit test	4.3.4.2					
Gear test	4.3.4.3					
Sound level test	4.3.4.4					
Auxillary equipment test	4.3.4.5					
PREPARATION FOR SHIPMENT						
Preparation complete	4.4.1					
Paint	4.4.3.1					
Rust preventative (exterior and interior)	4.4.3.2/4.4.3.3					
Tags complete	4.4.3.9/4.4.5					
Installation instructions shipped	4.4.1.5					

APPENDIX G—CORRESPONDING INTERNATIONAL STANDARDS

Table G-1—Corresponding International Standards (See Note)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ANSI/ABMA Std 7	Shaft and housing fits for metric bearings	286-1 286-2	5425	5656 Part 1 5656 Part 2	NFE 22396	B0401 B1566
ANSI/ABMA Std 9	Load ratings and fatigue life for ball bearings	281 76	622	5512 Part 1	NF ISO 281	B1518 B1519
ANSI/ABMA	Metric bearings: bounder dimensions	15 492 5753		6107 Part 3	NF ISO 5753	B1512 B1513 B1514 B1520
ANSI/AGMA 9000	Balance classification flexible couplings	1940/1 8821 5406	VDI 2060 740 Part A	6861 Part 1	NFE 90600	B0905 B0906
ANSI/AGMA 9002	Bores and keyways flexible couplings	R 773 R 774 R 775 286-1 286-2	740 6885 7190	3170 4235	NFE 02-E22175 NF ISO 286-1 NF ISO 286-2	B0903 B0904 B1301 B1303
ANSI/ASME B 1.1	Screw threads	262 (Metric)		3643 (Metric)	NFE 03-014	B0205 B0207 B0209 B0211
ANSI/ASME B1.20.1	General purpose pipe threads	228 PT.1 (Seal on gasket)		2779 (Seal on thread) 21 (Seal on thread)	NFE 03.005	B0202 B0203
ANSI/ASME B 16.1	Cast iron pipe flanges	7005/2	2532 2533 2534 2535	4504	NFE 29206	
ANSI/ASME B 16.5	Steel and alloy pipe flanges	7005/1	2543 2544 2545 2546 2547 2548 2549 2550 2551	4504	NFE 29203/204	JPI-7S-15-1984
ANSI/ASME B 16.11	Forged fittings		910	3799	NFE 29600	
ANSI/ASME B 16.42	Ductile iron flanges and fittings					
ANSI/ASME B 31.3	Chemical plant and petroleum refinery piping			1600		B8270
ANSI/ASME Y 14.2M	Line conventions and lettering	31 128 129 3098		308 Parts 2 & 3	NFE 04202/203	

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval (see 2.1).

Table G-1—Corresponding International Standards (See Note)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ANSI/AWS D 1.1	Structural welding code–steel			4870/1/2	NFP 22471	Code of Japan Welding Eng. Society
API Std 520	Design of pressure-relieving systems					
API Std 526	Flanged steel safety relief valves					
API Std 612	Special purpose steam turbines					
API Std 614	Lubrication systems	10438	24425	4807		
API Std 670	Vibration position and bearing temperature monitoring	2372 3945	VDI 2056 VDI 2059	4675	NFE 90300 NFE 90301	
API Std 671	Special purpose couplings					
API Std 677	General purpose gear units					
ASME Boiler and Pressure Vessel Code: –Section II	Pressure casing: design and construction: Materials		AD-MERK-BLÄTTER			
–Section V	Nondestructive examination		SEC. HP 5/3	4080 Parts I & II		G0801 Z2343 Z2344 Z3060
–Section VIII Div. 1	Rules for construction of pressure vessels	R 831 TR 7468		5500	CODAP	B8270 G0565 Z2202
–Section IX	Welding and brazing		SEC. HP 2 SEW 110 8560/63	4870/1/2		Z2242 Z3040 Z3801 Z3881 Z3891
ASME PTC 6	Steam turbine testing					
ASTM A53	Zinc coated welded and seamless black and hot dipped steel pipe					G3452/ G3454
ASTM A105	Carbon steel forgings for piping components		1629 17155	1503	NFA 49.281	G3201 G3202 G4051
ASTM A106	Seamless carbon steel pipe for high-temperature service		17175	3602	NFA 49.211	G3456
ASTM A153	Zinc coating (hot dip) on iron and steel hardware			1706		B3201
ASTM A193	Alloy steel and stainless steel bolting materials for high-temperature service		17240/17440 17200/17245 17440	4882 1506	NFA 35558	G4107 G4303
ASTM A194	Carbon and alloy steel nuts for bolts for high-pressure and high-temperature service		17440	4882 1506		G4051 G4303
ASTM A197	Cupola malleable iron					G5702

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval (see 2.1).

Table G-1—Corresponding International Standards (See Note)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ASTM A269	Seamless and welded austenitic stainless steel tubing for general service		17440	3605	NFA 49117	G3463
ASTM A278	Gray iron castings for pressure containing parts	185	1691 AD W 3/1 TRD 108	1452		G5501
ASTM A307 Gr B	Carbon steel bolts and studs					
ASTM A312	Stainless and welded austenitic stainless steel pipe		17440	3605	NFA 49214/49219	G3459
ASTM A320	Alloy steel bolting material					
ASTM A338	Malleable iron flanges, pipe fittings, and valve parts for railroad, marine, and other heavy duty service at temperatures up to 650°F (345°C)					G5702
ASTM A388	Ultrasonic examination					
ASTM A395	High-temperature ductile iron castings					
ASTM A536	Ductile iron castings					
ASTM A524	Seamless carbon steel pipe for atmospheric and lower temperatures					G3460
ASTM E94	Guides for radiographic testing		5411/T.1 & 2	2737 (For Castings)	UFA 04160 (For Castings)	G0581 Z3104 Z3106
ASTM E125	Ref. photographs for magnetic indications		1650	4080 (For Acceptance Criteria)		G0565
ASTM E142	Controlling quality of radiographic testing		54109	3971		G0581 Z3104 Z3106
ASTM E709	Practice for magnetic particle examination		54130	6072	NFA 04193/ A09590	G0565
MSSG-SP-55	Quality standard for steel castings for valves, flanges, and fittings and other piping components (visual method)					
NEMA MG-1	Motors and generators					
NEMA SM 23	Steam turbines for mechanical drive service					
NFPA 70	National Electrical Code	79			NFC 02/205U	JEAC8001
SSPC SP 6	Commercial blast cleaning			7079		

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval (see 2.1).

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