

General-Purpose Steam Turbines For Refinery Service

API STANDARD 611
THIRD EDITION, AUGUST 1988

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



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Refining Department

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American
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Institute



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 the 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.

API standards are published as an aid to procurement of standardized equipment and materials. These standards are not intended to inhibit purchasers or producers from purchasing or producing products made to specifications other than those of API.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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 (EPA) 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.

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General-Purpose Steam Turbines for Refinery Service

SECTION 1—GENERAL

1.1 Scope

1.1.1 This standard covers the minimum requirements for general-purpose steam turbines for refinery service. 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.

1.1.2 Steam turbines are classified as general- or special-purpose according to service requirements. The purchaser will specify the type of turbine that is best suited to his needs.

1.1.2.1 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 noncritical service. They are generally used where steam conditions will not exceed a pressure of 700 pounds per square inch gauge (48 bar gauge) and a temperature of 750°F (400°C) or where speed will not exceed 6000 revolutions per minute.

1.1.2.2 Special-purpose turbines are horizontal turbines used to drive equipment that is usually not spared, is relatively large in size (power), or is in critical service. The use of special-purpose turbines 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.

1.4 Definition of Terms

Terms used in this standard are defined in 1.4.1 through 1.4.26.

1.4.1 *Axially split* refers to casing joints that are parallel to the shaft centerline.

1.4.2 A *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.

1.4.3 *Hydrodynamic bearings* are 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.

1.4.4 *Maximum allowable speed* (in revolutions per minute) is the highest speed at which the manufacturer's design will permit continuous operation (see note to 2.1.4, Item e).

1.4.5 *Maximum allowable temperature* is 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 (see note to 2.1.4, Item e).

1.4.6 *Maximum allowable working pressure* is 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 (see note to 2.1.4, Item e).

1.4.7 *Maximum continuous speed* (in revolutions per minute) is the speed at least equal to 105 percent of the highest speed required by any of the specified operating conditions.

1.4.8 *Maximum exhaust pressure* is the highest exhaust steam pressure at which the turbine is required to operate continuously.

1.4.9 *Maximum exhaust casing pressure* is the highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions.

1.4.10 *Maximum inlet pressure and temperature* refer to the highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

1.4.11 *Minimum allowable speed* (in revolutions per minute) is the lowest speed at which the manufacturer's design will permit continuous operation (see note to 2.1.4, Item e).

1.4.12 *Minimum exhaust pressure* is the lowest exhaust steam pressure at which the turbine is required to operate continuously.

1.4.13 *Minimum inlet pressure and temperature* refer to the lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

1.4.14 *NEMA inlet and exhaust conditions* are equivalent to the maximum inlet and exhaust steam conditions specified on the data sheets.

1.4.15 *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.

1.4.16 *Oil mist lubrication* refers to lubrication systems that employ oil mist produced by atomization in a central supply unit and transported to the bearing housing by compressed air.

1.4.17 *With purge oil mist lubrication* (wet sump), the mist only purges the bearing housing. Bearing lubrication is by conventional oil bath, flinger, or oil ring.

1.4.18 *With pure oil mist lubrication* (dry sump), the mist both lubricates the bearing and purges the housing.

1.4.19 *Potential maximum power* is 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 valve or valves.

1.4.20 The *pressure casing* is the composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

1.4.21 *Radially split* refers to casing joints that are transverse to the shaft centerline.

1.4.22 *Rated* applies to the greatest turbine power specified and the corresponding speed. It includes all of the margin required by the driven-equipment specifications.

1.4.23 *Standby service* refers to a normally idle or idling piece of equipment that is capable of immediate automatic or manual start-up and continuous operation.

1.4.24 *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.

1.4.25 *Trip speed* (in revolutions per minute) is 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 (see 3.4.2.7).

1.4.26 *Unit responsibility* refers to the technical responsibility for coordinating the general arrangement of the driver and driven equipment, as well as power requirements, speed, direction of rotation, and so forth; for designing and laying out lubrication and sealing systems; for analyzing vibration and noise data; and for supervising and coordinating all required tests and material reports for all equipment within the scope of this standard.

1.4.27 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.

1.5 Referenced Publications

1.5.1 The following standards, codes, and specifications are cited in this standard:

AFBMA¹

- 7 *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*
- 9 *Load Ratings and Fatigue Life for Ball Bearings*
- 20 *Metric Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*

AGMA²

- 514 *Load Classification and Service Factors for Flexible Couplings*
- 515 *Balance Classification for Flexible Couplings*
- 9002-A86 *Bores and Keyways for Flexible Couplings (Inch Series)*

¹Anti-Friction Bearing Manufacturers Association, 1235 Jefferson Davis Highway, Arlington, Virginia 22202.

²American Gear Manufacturers Association, 1901 North Fort Myer Drive, Arlington, Virginia 22209.

ANSI¹

- B1.1 *Unified Inch Screw Threads (UN and UNR Thread Forms)*
 B16.1 *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800*
 B16.5 *Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys*
 B16.11 *Forged Steel Fittings, Socket-Welding and Threaded*
 B16.42 *Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300*
 B17.1 *Keys and Keyseats*
 Y14.2M *Line Conventions and Lettering*

API

- Spec 5L *Specification for Line Pipe*
 RP 550 *Manual on Installation of Refinery Instruments and Control Systems*
 Std 612 *Special-Purpose Steam Turbines for Refinery Services*
 Std 614 *Lubrication, Shaft-Sealing, and Control-Oil Systems for Special-Purpose Applications*
 Std 615 *Sound Control of Mechanical Equipment for Refinery Services*
 Std 670 *Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*
 Std 677 *General-Purpose Gear Units for Refinery Services*
 Std 678 *Accelerometer-Based Vibration Monitoring System*

ASME⁴

- B1.20.1 *Pipe Threads, General Purpose*
 B31.3 *Chemical Plant and Petroleum Refinery Piping*
 PTC 6 *Performance Test Code—Steam Turbines*
Boiler and Pressure Vessel Code, Section V, "Non-destructive Examination," Section VIII, "Pressure Vessels," and Section IX, "Welding and Brazing Qualifications"

ASTM⁵

- A 53 *Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*
 A 105 *Forgings, Carbon Steel, for Piping Components*
 A 106 *Seamless Carbon Steel Pipe for High-Temperature Service*

- A 120 *Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses*
 A 153 *Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
 A 181 *Forgings, Carbon Steel for General Purpose Piping*
 A 193 *Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service*
 A 194 *Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service*
 A 197 *Cupola Malleable Iron*
 A 269 *Seamless and Welded Austenitic Stainless Steel Tubing for General Service*
 A 278 *Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (345°C)*
 A 307 *Carbon Steel Externally Threaded Standard Fasteners*
 A 312 *Seamless and Welded Austenitic Stainless Steel Pipe*
 A 325 *High-Strength Bolts for Structural Steel Joints*
 A 338 *Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine, and Other Heavy Duty Service at Temperatures Up to 650°F (345°C)*
 A 388 *Ultrasonic Examination of Heavy Steel Forgings*
 A 395 *Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*
 A 515 *Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*
 A 536 *Ductile Iron Castings*
 E 94 *Guides for Radiographic Testing*
 E 125 *Reference Photographs for Magnetic Particle Indications on Ferrous Castings*
 E 142 *Method for Controlling Quality of Radiographic Testing*
 E 709 *Magnetic Particle Examination*

AWS⁶

- D1.1 *Structural Welding Code—Steel*

MSS⁷

- SP 55 *Quality Standard for Steel Castings—Visual Method*

¹American National Standards Institute, 1430 Broadway, New York, New York 10018.

⁴American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

⁵American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

⁶American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33135.

⁷Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, N.E., Vienna, Virginia 22180.

NEMA⁸

- MG 1 *Motors and Generators*
 SM 23 *Steam Turbines for Mechanical Drive Service*

NFPA⁹

- 70 *National Electrical Code*, Chapter 5, Article 500, "Hazardous (Classified) Locations," and Article 501, "Class I Locations"

OSHA¹⁰

Occupational Safety and Health Standards of the U.S. Department of Labor

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

SECTION 2—BASIC DESIGN

2.1 General

2.1.1 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.

2.1.2 The vendor shall assume responsibility for the engineering coordination of the equipment and all auxiliary systems included in the scope of the order.

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

2.1.4 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 3.4.1.4 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.

⁸National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037.

⁹National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.

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.

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

2.1.6 Single-stage turbines shall be suitable for immediate start-up to full load without a preliminary warmup 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.

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

2.1.8 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.

2.1.9 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.

¹⁰Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C. 20310.

2.1.10 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.

2.1.11 Unless otherwise specified, cooling water systems shall be designed for the following conditions:

Velocity over heat exchanger surfaces	5-8 ft/s	1.5-2.5 m/s
Maximum allowable working pressure	≥75 psig	≥5.2 bar (ga)
Test pressure	≥115 psig	≥7.9 bar (ga)
Maximum pressure drop	15 psi	1 bar
Maximum inlet temperature	90°F	32°C
Maximum outlet temperature	120°F	49°C
Maximum temperature rise	30°F	17°C
Fouling factor on water side	0.002 hr-ft ² -°F/Btu	0.35 m ² -K/kW
Shell corrosion allowance	0.125 in.	3.2 mm

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

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

2.1.12 Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. Unless otherwise specified, the equipment furnished by the vendor shall conform to the requirements of API Standard 615 and the maximum allowable sound pressure level specified.

2.1.13 Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division) specified by the purchaser on the data sheets and shall meet the requirements of NFPA 70, Articles 500 and 501, as well as local codes specified and furnished by the purchaser (see 3.4.5.4).

2.1.14 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 and unusual humidity or dust problems). The unit and its auxiliaries shall be suitable for operation under these specified conditions.

2.1.15 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.

2.1.16 When specified, the equipment feet shall be equipped with vertical jackscrews.

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

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

2.2 Pressure Casings

2.2.1 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.

2.2.2 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.

2.2.3 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.

2.2.4 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.

2.2.5 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.

2.2.6 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 0.002 inch (50 micrometers). 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 0.002 inch per foot (1:6000). Corresponding surfaces shall be coplanar

within 0.002 inch per foot of distance between surfaces (0.17 millimeter per meter).

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

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

2.2.9 Jackscrews, guide rods (for multistage turbines), and 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.

2.2.10 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.

2.2.11 Bolting shall be furnished as specified in 2.2.11.1 through 2.2.11.6.

2.2.11.1 The details of threading shall conform to ANSI B1.1.

2.2.11.2 Studs are preferred to cap screws.

2.2.11.3 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 1½ times the major diameter of the stud; the first 1½ threads at both ends of each stud shall be removed.

2.2.11.4 The minimum material quality of bolting for pressure joints shall be carbon steel (ASTM A 307, Grade B) for cast iron parts and a high-temperature alloy steel (ASTM A 193, Grade B-7) for steel and alloy parts. Carbon steel (ASTM A 325) may be used for parts where the temperature is below 500°F (260°C). Nuts shall conform to ASTM A 194, Grade 2H (or, where space is limited, to ASTM A 307, Grade B, case-hardened).

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

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

2.2.12 The machined finish of the mounting surface shall be 125–250 microinches (3.2–6.4 micrometers) 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.

2.3 Casing Appurtenances

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

2.4 Casing Connections

- 2.4.1 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 1.4.8 and 1.4.9.

2.4.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping.

2.4.3 Casing openings for piping connections shall be at least ¼ inch nominal pipe size. Threaded openings are permissible in sizes ¼ inch, 1 inch, and 1½ inches nominal pipe size. Openings shall be installed as specified in 2.4.3.1 through 2.4.3.7.

2.4.3.1 A pipe nipple, preferably not more than 6 inches (150 millimeters) long, shall be connected to the opening.

2.4.3.2 Pipe nipples shall be a minimum of Schedule 160 seamless for sizes 1 inch and smaller and a minimum of Schedule 80 seamless for a size of 1½ inches.

2.4.3.3 Pipe nipples shall be provided with welding-neck or socket-weld flanges for steam pressures of 180 pounds per square inch gauge (12.4 bar gauge) or higher.

2.4.3.4 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.

2.4.3.5 Tapped openings and bosses for pipe threads shall conform to ANSI B16.5.

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

2.4.3.7 Openings for socket-welded connections shall conform to ANSI B16.11.

2.4.4 Openings for nominal pipe sizes of 1¼, 2½, 3½, 5, 7, and 9 inches shall not be used.

2.4.5 Tapped openings not connected to piping shall be plugged with solid round-head steel plugs furnished in accordance with ANSI 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. Threads shall be lubricated. Plastic plugs are not permitted.

2.4.6 Flanges shall conform to ANSI B16.1 or B16.5, or B16.42 as applicable, except as specified in 2.4.6.1 through 2.4.6.5.

2.4.6.1 Cast iron flanges shall be flat faced and shall have a minimum thickness of Class 250 in accordance with ANSI B16.1 for sizes 8 inches and smaller. Exhaust flanges 10 inches and larger may be Class 125.

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

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

2.4.6.4 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.

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

2.4.7 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.

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

2.4.9 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

Table 1—Arithmetic Average Roughness Height (R_a)

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

be of rabbeted design, flat-faced with a provision for accurate centering and doweling conforming to NEMA MG 1, or as specified.

2.5 External Forces and Moments

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

2.6 Rotating Elements

2.6.1 ROTORS

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

2.6.1.2 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.

2.6.1.3 The purchaser's specific approval is required for built-up rotors when blade tip velocities at maximum continuous speed exceed 825 feet per second (250 meters per second) or when stage inlet steam temperatures exceed 825°F (441°C).

2.6.2 SHAFTS

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

2.6.2.2 When noncontacting vibration or axial position probes are furnished or 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. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be 16–32 microinches (0.4–0.8 micrometer) R_a , preferably obtained by honing or burnishing. These areas shall be properly demagnetized or otherwise treated so that

the combined total of 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, 0.25 mil (6 micrometers).
- b. For areas to be observed by axial position probes, 0.5 mil (13 micrometers).

2.6.2.3 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.

2.6.2.4 Keyways shall have fillet radii that conform to ANSI B17.1.

2.6.3 BLADING

2.6.3.1 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.

2.6.3.2 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.

2.7 Seals

2.7.1 Outer glands shall be sealed at the shaft by carbon-ring or replaceable labyrinth packing or both.

2.7.2 Carbon-ring packing shall be used only when the rubbing speed at the shaft sealing surface is less than 160 feet per second (49 meters per second). The number of carbon rings shall be determined by the service and venting requirements, with 35 pounds per square inch (2.41 bar) 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.

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

- **2.7.4** 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.

- **2.7.5** 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.

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

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

2.7.8 The gland casing leak-off connections shall comply with 2.4.2.

2.8 Dynamics

2.8.1 CRITICAL SPEEDS

2.8.1.1 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.

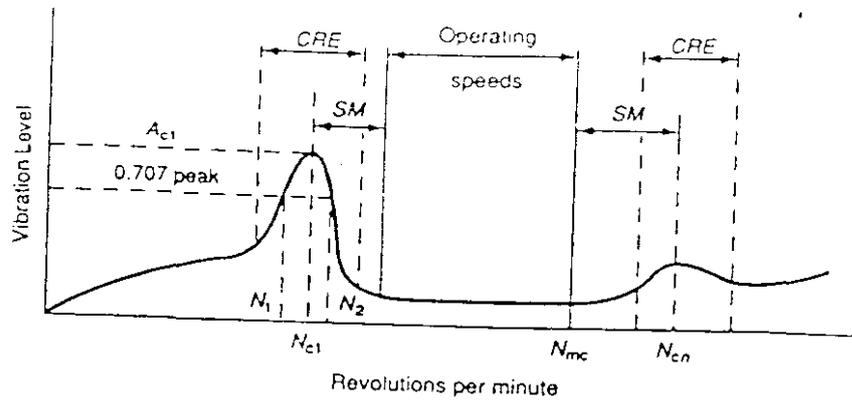
2.8.1.2 A rotor-bearing support system in resonance will have its normal vibration displacement amplified. The magnitude of amplification and the rate of phase-angle change are related to the amount of damping in the system and to the mode shape taken by the rotor.

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, . . . , *n*th) bending mode.

2.8.1.3 When the rotor amplification factor (see Figure 1), as measured at the vibration probe, is greater than or equal to 2.5, that frequency is called critical, and the corresponding shaft rotational frequency is 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.

2.8.1.4 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.



- N_{c1} = Rotor first critical, center frequency, cycles per minute.
- N_{cn} = Critical speed, n th.
- N_{mc} = Maximum continuous speed, 105 percent.
- N_1 = Initial (lesser) speed at $0.707 \times$ peak amplitude (critical).
- N_2 = Final (greater) speed at $0.707 \times$ 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} .

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

Figure 1—Rotor Response Plot

- 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.

2.8.1.5 Resonances of support systems within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins unless the resonances are critically damped.

2.8.1.6 The vendor who is specified to have unit responsibility shall determine that the drive-train critical speeds (rotor lateral, system torsional, blading modes, and the like) are compatible with the critical speeds of the machinery being supplied and that the combination 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 5.2.5.2).

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

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

2.8.2 LATERAL ANALYSIS

2.8.2.1 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.

2.8.2.2 When specified, the vendor shall provide calculations and/or available supporting test data for separation margins in accordance with 2.8.1.8 and B.1.4.

2.8.3 TORSIONAL ANALYSIS

2.8.3.1 Excitations of torsional resonances may come from many sources that 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 (under inertial impedances) and other torsional oscillations.
- c. Hydraulic-governor control-loop resonances.

2.8.3.2 The vendor who has unit responsibility shall ensure that the torsional resonances 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).

2.8.3.3 Torsional criticals at two or more times running speed 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. The purchaser and the vendor shall be mutually responsible for identifying these frequencies.

2.8.3.4 When torsional resonances are calculated to fall within the margin specified in 2.8.3.2, 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.

- 2.8.3.5 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 2.8.3.1 through 2.8.3.4.

2.8.4 VIBRATION AND BALANCING

2.8.4.1 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.

- 2.8.4.2 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 (see Appendix C). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

$$U_{\max} = 4WIN$$

In SI units,

$$U_{\max} = 6350W/N$$

Where:

U_{\max} = residual unbalance, in ounce-inches (gram-millimeters).

W = journal static weight load, in pounds (kilograms).

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.

- 2.8.4.3 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 (see Appendix C).

2.8.4.4 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.

2.8.4.5 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 2.0 mils (50 micrometers), whichever is less:

$$A = \sqrt{\frac{12,000}{N}} \quad (1)$$

In SI units,

$$A = 25.4 \sqrt{\frac{12,000}{N}}$$

Where:

- A = amplitude of unfiltered vibration, in mils (micrometers) 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.

2.8.4.6 When specified, electrical and mechanical runout shall be determined and recorded by rolling the rotor in V blocks while measuring runout with a noncontacting vibration probe and a dial indicator at the same shaft location.

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

2.8.4.8 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 percent of the test level calculated from Equation 1 or 0.25 mil (6 micrometers), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

2.8.4.9 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 2.8.4.5 shall not exceed 0.15 inch (3.8 millimeters) per second (unfiltered) and 0.10 inch (2.5 millimeters) per second at running speed frequency (filtered).

2.9 Bearings and Bearing Housings

2.9.1 Hydrodynamic radial bearings shall be required under the following conditions:

- a. Where antifriction-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 L_{10} rating life (see AFBMA 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 first evidence of failure.)

- 2.9.2 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 L_{10} rating life (see 2.9.1, Item a).

- 2.9.3 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.

2.9.4 Antifriction bearings shall be retained on the shaft and fitted into housings in accordance with the requirements of AFBMA 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.

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

2.9.6 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. 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 (see 2.8.4.5) while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency. 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.

2.9.7 Hydrodynamic thrust bearings shall be in accordance with 2.9.7.1 through 2.9.7.3.

2.9.7.1 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.

2.9.7.2 Replaceable thrust collars shall be positively locked to the shaft to prevent fretting. When integral thrust collars are furnished, they shall be provided with at least $\frac{1}{8}$ inch (3.2 millimeters) of additional stock to enable refinishing if the collar is damaged.

2.9.7.3 Both faces of thrust collars shall have a surface finish of not more than 16 microinches (0.4 micrometer) R_a , and the axial runout shall not exceed 0.0005 inch (12.7 micrometers) TIR after the collar is mounted on the shaft.

- 2.9.8 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 2.9.8.1 through 2.9.8.3 and as specified by the manufacturer of the driven equipment.

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

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

In SI units,

$$F = \frac{(0.25)(95,540)P_r}{(N_r D)}$$

Where:

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

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

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

2.9.8.3 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.

2.9.9 Hydrodynamic thrust bearings shall be selected at no more than 50 percent of the bearing manufac-

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

- a. The shaft speed.
- b. The temperature of the bearing babbitt.
- c. The deflection of the bearing pad.
- d. The minimum oil-film thickness.
- e. The feed rate, viscosity, and supply temperature of the oil.
- f. The design configuration of the bearing.
- g. The babbitt alloy.
- h. The turbulence of the oil film.

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

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

2.9.12 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 50°F (28°C) under the most adverse specified operating conditions. The bearing-oil outlet temperature shall not exceed 160°F (71°C). For oil-flooded designs, the oil outlets from thrust bearings shall be in the upper half of the control ring or, if control rings are not used, in the thrust-bearing cartridge.

2.9.13 Oil inlet and drain connections shall be flanged or machined and studded. Threaded openings are permissible in $\frac{3}{4}$ inch, 1 inch, and 1½ inch nominal pipe sizes. Pipe connections in 1½-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 3/4-inch and 1-inch connections shall not be seal welded.

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

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

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

2.9.17 Bearing housings for oil-lubricated non-pressure-fed bearings shall be provided with tapped and plugged fill and drain openings at least 1/2-inch National Pipe Thread (NPT) in size. The housings shall be equipped with constant-level sight-feed oilers at least 4 ounces (0.12 liter) in size, with a positive level positioner (not an external screw), heat-resistant glass containers, 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.

2.9.18 Housings 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.

2.9.19 The requirements specified in 2.9.19.1 through 2.9.19.5 apply when oil mist lubrication is specified.

2.9.19.1 An oil mist inlet connection, 1/4 inch nominal pipe size, 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 that makeup oil will drip into the bearings.

2.9.19.2 A vent connection, 1/4 inch nominal pipe size, shall be provided on the housing or end cover

for each of the spaces between antifriction bearings and the housing shaft closures. Alternatively, where oil mist connections are between each housing shaft closure and the bearings, one vent central to the housing shall be supplied. Housings that have only sleeve-type bearings shall have the vent located near the end of the housing.

2.9.19.3 Shielded or sealed bearings shall not be used.

2.9.19.4 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.

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

2.9.20 Sufficient cooling capacity, including an allowance for fouling, shall be provided to maintain the oil temperature below 160°F (71°C) for pressurized systems and below 180°F (82°C) for ring-oiled or splash systems, based on the specified operating conditions and an ambient temperature of 110°F (43°C). Where cooling is required for ring-oiled or splash-lubricated bearings, either a circulating oil system or water jackets in the bearing housings shall be provided. Water jackets 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 0.042 inch (1.07 millimeters) and shall be at least 0.50 inch (12.7 millimeters) in diameter.

- 2.9.21 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 2.6.2.2.

2.10 Lubrication

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

2.10.2 Oil flingers shall be positively secured to the shaft and shall have mounting hubs to maintain concentricity.

- 2.10.3 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.

- 2.10.4 Where a wide-speed-range, rapid-starting, or slow-roll operation is required, these conditions will be specified, and lubrication of the turbine and gear shall be given special consideration.

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

- 2.10.6 Turbines that have pressure lubrication systems (other than self-contained governors) shall include the following (see Appendix D for a schematic of a minimum system):

a. An oil reservoir fabricated from AISI¹¹ Standard Type 300 stainless steel that has the following characteristics and appendages:

1. The capacity to avoid frequent refilling and to provide adequate allowance for system rundown. The reservoir should also be sized to provide 4 minutes of system consumption but not less than 2 minutes of pump capacity at normal speed. System consumption is pump-delivered flow minus pressure-control-valve flow.
2. Provisions to eliminate air and minimize flotation of foreign matter to pump suction.
3. A fill connection, armored gauge glass with level indication, and a breather suitable for outdoor use.
4. A sloped bottom and connection for complete drainage.
5. A cleanout opening as large as practicable.

b. 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.

c. Either oil rings or a hand-operated standby pump for start-up lubrication, if required by the vendor.

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

e. A full-flow filter with replaceable elements and filtration of 25 microns nominal or finer. Filter cartridge materials 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.

f. A temperature gauge after the oil cooler.

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

h. Low-oil-pressure shutdown device.

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

j. When specified, a sight flow indicator in each bearing-oil drain line.

k. When specified, a low-oil-pressure alarm switch.

l. When specified, a low-oil-pressure shutdown switch.

2.10.7 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. (Refer to 3.5.2 for lubricating-oil piping requirements.)

- 2.10.8 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 15 watts per square inch (2.33 watts per square centimeter).

2.11 Materials

2.11.1 GENERAL

2.11.1.1 Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required by the data sheets or this standard (see 3.5 for requirements for auxiliary piping materials).

2.11.1.2 Materials shall be identified in the proposal with their applicable ASTM, AISI, ASME, or SAE¹² numbers, including the material grade. When no such designation is available, the vendor's material specification, giving physical properties, chemical compo-

¹¹American Iron and Steel Institute, 1000 16th St., N.W., Washington, D.C. 20036.

¹²Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

sition, and test requirements, shall be included in the proposal.

2.11.1.3 Pressure parts shall be made of steel if the maximum steam conditions to which they may be subjected exceed 250 pounds per square inch gauge (17 bar effective) or 500°F (260°C) or if the normal steam temperature exceeds 450°F (232°C). Exhaust casings of noncondensing turbines shall be made of steel if the maximum exhaust pressure may exceed 75 pounds per square inch gauge (5.2 bar effective) or if the no-load exhaust temperature may exceed 500°F (260°C). Suitable alloy steel shall be used where the maximum steam temperatures may exceed 750°F (400°C). Ductile iron may be used only with the approval of the purchaser.

2.11.1.4 Material for other turbine parts shall be the manufacturer's standard for the shaft and wheels, 11-13Cr for blading and nozzles (rotating and stationary), and 11-13Cr or nickel-copper alloy for the shrouding and steam strainer.

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

2.11.1.6 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.

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

2.11.1.8 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.

2.11.1.9 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 A 515 is prohibited.

2.11.1.10 For ambient temperatures below -20°F (-29°C), 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.

2.11.2 CASTINGS

2.11.2.1 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.

2.11.2.2 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.

2.11.2.3 Ferrous castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 2.11.2.3.1 and 2.11.2.3.2.

2.11.2.3.1 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.

2.11.2.3.2 Cast gray 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.

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

2.11.2.5 Nodular iron castings shall be produced and tested for physical and chemical properties in accordance with ASTM A 395.

2.11.3 WELDING

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

2.11.3.2 The vendor shall be responsible for establishing weld repair procedures that are in compliance with the requirements of the ASME Code and for the implementation of repairs in accordance with these procedures, including post-repair heat treatment and, if required, nondestructive examination. Unless otherwise specified, all welding other than that covered by ASME B31.3 and Section VIII, Division 1, of the ASME Code, such as welding on baseplates, non-

pressure ducting, lagging, and control panels, shall be performed in accordance with AWS D1.1.

2.11.3.3 Pressure-containing castings made of wrought materials or combinations of wrought and cast materials that are under internal pressure greater than 300 pounds per square inch gauge (20 bar gauge) shall have all accessible weld surfaces inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after stress relieving (see 4.2.2.1.2).

2.11.3.4 Fabricated casings, regardless of their thickness, shall be post-weld heat treated.

2.12 Nameplates and Rotation Arrows

2.12.1 Nameplates and rotation arrows shall be made of AISI Standard Type 300 stainless steel or nickel-copper alloy (Monel or its equivalent), securely fastened by pins of similar material, and located for easy visibility. Welding is not permitted.

2.12.2 The data sheets shall specify whether English or metric 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. (If critical speed values are not obtained by test, the word "calc" shall be stamped beside the number. Any critical speeds below maximum continuous speed shall be determined on the test stand.)
- f. Second critical speed. (If critical speed values are not obtained by test, the word "calc" shall be stamped beside the number. Any critical speeds below maximum continuous speed shall be determined on the test stand. Second critical speed is omitted for turbines that run below first critical speed.)
- g. Maximum continuous speed.
- h. Minimum allowable speed.
- i. Overspeed trip setting (see 3.4.2.2).
- 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).

SECTION 3—ACCESSORIES

3.1 Gear Units

3.1.1 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.

3.1.2 Integral (built-in) gear units shall not be used for driven equipment that requires more than 75 rated horsepower (56 kilowatts).

3.1.3 Unless otherwise specified, separate parallel-shaft gear units up to 2000 horsepower (1500 kilowatts) shall conform to API Standard 677.

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

3.2 Couplings and Guards

3.2.1 Unless otherwise specified, flexible 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.

3.2.2 The make, type, and mounting arrangement of the couplings and guards shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. The coupling rating shall be at least equal to the turbine rated power times the coupling service factor for the application in accordance with AGMA 514. Unless otherwise specified, a spacer coupling with a minimum 5-inch (125-millimeter) spacer shall be used. Couplings shall be made of forged steel and designed to allow the necessary end float caused by expansion and other end movements of the shaft.

3.2.3 Information about shafts, keyway dimensions, and shaft end movements caused by end play and thermal effects shall be furnished to the vendor who supplies the coupling.

3.2.4 The power rating of the coupling-to-shaft junction shall be at least equal to the turbine rated power times the coupling service factor for the application in accordance with AGMA 514.

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

3.2.6 To assure accurate alignment of connected machinery, the total indicator reading of coupling registration and alignment surfaces shall be controlled as specified in 3.2.6.1 through 3.2.6.3.

3.2.6.1 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: 0.0005 inch (13 micrometers) TIR per inch of shaft diameter, with a minimum applicable tolerance of 0.001 inch (25 micrometers) TIR and a maximum of 0.003 inch (75 micrometers) 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.

3.2.6.2 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 3.2.6.1.

3.2.6.3 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 3.2.6.1. Coupling registration faces shall be perpendicular to the axis of the coupling within 0.0001 inch per inch of face diameter with a maximum of 0.0005 inch (13 micrometers) TIR.

3.2.7 Couplings shall be keyed in place. Keys, keyways, and fits shall conform to AGMA 9002-A86. Cylindrical shafts shall have the interference fit specified in AGMA 9002-A86. Where tapered shafts are specified or required, the taper shall conform to NEMA SM 23. Coupling hubs shall be furnished with tapped puller holes at least $\frac{3}{8}$ inch (10 millimeters) in size to aid removal. Unless otherwise specified, couplings shall be manufactured to meet the balance requirements of AGMA 515, Class 8.

3.2.8 When specified by the purchaser or recommended by the vendor, couplings shall be dynamically balanced in accordance with AGMA 515. For dynamic balancing, the AGMA balance class shall be mutually agreed upon by the purchaser and the vendor.

3.2.9 An easily removable coupling guard shall be placed over each exposed coupling furnished by the vendor. Each coupling guard shall be in accordance with the requirements of the Occupational Safety and Health Administration.

3.3 Mounting Plates

3.3.1 GENERAL

3.3.1.1 The equipment shall be furnished with soleplates or a baseplate, as specified on the data sheets.

3.3.1.2 In 3.3.1.2.1 through 3.3.1.2.10 the term *mounting plate* refers to both baseplates and soleplates.

3.3.1.2.1 The mounting surfaces for the equipment feet shall extend 1 inch (25 millimeters) beyond the sides of the feet and shall be machined flat and parallel within 0.002 inch per foot (1:6000). Corresponding surfaces shall be in the same plane within 0.002 inch per foot of distance between the mounting surfaces (0.17 millimeter per meter). This requirement shall be met by supporting and clamping the mounting plate at the foundation bolt holes only.

3.3.1.2.2 Mounting plates shall be equipped with vertical jackscrews.

3.3.1.2.3 When the equipment supported weighs more than 1000 pounds (450 kilograms), the mounting plates shall be furnished with horizontal 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 they do not interfere with the installation or removal of the equipment.

3.3.1.2.4 Mounting plates shall be designed to limit a change of alignment caused by the worst combination of pressure, torque, and allowable piping stress to 0.002 inch (50 micrometers) at the coupling flange. (See 2.5 for allowable piping forces.)

3.3.1.2.5 When epoxy grout is specified on the data sheets, the vendor shall precoat all the grouting surfaces of the mounting plates with a catalyzed epoxy primer applied to *degreased white metal*. The epoxy primer shall be compatible with epoxy grout. The vendor shall submit to the purchaser instructions for field preparation of the epoxy primer.

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

3.3.1.2.7 Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates that are to be grouted shall have 2-inch-radius (50-millimeter-radius) outside corners (in the plan view).

3.3.1.2.8 The vendor of the mounting plates shall furnish stainless steel shim packs at least $\frac{1}{8}$ inch (3 millimeters) thick between the equipment feet and the mounting plates. All shim packs shall straddle the hold-down bolts.

3.3.1.2.9 Anchor bolts will be furnished by the purchaser.

3.3.1.2.10 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.

3.3.2 BASEPLATE

- 3.3.2.1 When a baseplate is specified, the data sheets will indicate the major equipment to be mounted on it. The baseplate shall be a 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.

3.3.2.2 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.

- 3.3.2.3 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The mounting pads on the bottom of the baseplate shall be in one plane to permit use of a single-level foundation. When specified, subsoleplates shall be provided by the vendor.

3.3.2.4 All baseplates shall be provided with at least one grouting opening that has a clear area of no less than 19 square inches (0.01 square meter) and no dimension less than 3 inches (75 millimeters) in each bulkhead section. These holes shall be located to permit filling the entire cavity under the baseplate without creating air pockets. Where practical, holes shall be accessible for grouting with the turbine and driven equipment installed. Grout holes in the drip-pan area shall have ½-inch (13-millimeter) raised-lip edges. If the holes are located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of ¼ inch (2 millimeters) shall be provided. Vent holes at least ½ inch (13 millimeters) in diameter shall be provided at the highest points in each bulkhead section of the baseplate.

- 3.3.2.5 When decking is specified, it shall be a non-skid type covering all walk and work areas on top of the baseplate.

3.3.2.6 When specified, the baseplate shall be rigid enough to be mounted without grouting.

3.4 Controls and Instrumentation

3.4.1 GENERAL

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

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

3.4.1.3 Where applicable, controls and instrumentation shall conform to API Recommended Practice 550, API Standard 670, and API Standard 678.

- 3.4.1.4 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 2.1.4.2).

3.4.2 CONTROL SYSTEMS

3.4.2.1 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.

3.4.2.2 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.

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

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

- 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.
- 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.

3.4.2.5 Unless otherwise specified, the adjustable speed range of the governor and hand speed changer

Table 2—Speed Governors

Parameter	Class per NEMA SM 23	
	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.

shall be a total of 20 percent of the maximum continuous speed—5 percent greater and 15 percent less than normal speed.

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

3.4.2.7 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 250 pounds per square inch gauge (17.2 bar gauge) or higher.

3.4.2.8 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.

3.4.2.9 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.

3.4.3 GAUGE BOARDS AND INSTRUMENT PANELS

3.4.3.1 Gauge Boards

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

3.4.3.2 Instrument Panels

3.4.3.2.1 When specified, a panel shall be provided and shall be designed and fabricated in accordance

with the purchaser's description. The purchaser will specify whether the panel is to be located on the base of the unit or freestanding in another location. The instruments on the panel shall be clearly visible to the operator from the driver control point.

3.4.3.2.2 Panels shall be completely piped and wired, requiring only a 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 terminal posts mounted in a single terminal box that is attached to 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.

3.4.4 INSTRUMENTATION

3.4.4.1 Tachometers

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

3.4.4.2 Temperature Gauges

3.4.4.2.1 Dial-type temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 5 inches (127 millimeters) in diameter and bimetallic or mercury filled. Black printing on a white background is standard for gauges.

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

3.4.4.3 Thermowells

Temperature gauges that are located in pressurized or flooded lines shall be furnished with ¼-inch (19-millimeter) National Pipe Thread (NPT) separable solid-bar thermowells made of AISI Standard Type 300 stainless steel.

3.4.4.4 Pressure Gauges

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, 4½-inch (114-millimeter) dials and ½-inch NPT male alloy steel connections. Black printing on a white background is standard for gauges. When

specified, oil-filled gauges shall be furnished in locations subject to vibration. 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.

3.4.4.5 Solenoid Valves

Solenoid valves shall have a continuous service rating with Class F insulation.

3.4.5 ALARMS AND SHUTDOWNS

3.4.5.1 General

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

3.4.5.2 Sentinel Warning Valve

When specified, a sentinel warning valve shall be supplied on the turbine casing. For condensing turbines, it shall be set at 5 pounds per square inch gauge (0.35 bar gauge). For noncondensing turbines, the minimum setting shall be either 10 percent or 10 pounds per square inch gauge (0.7 bar gauge) 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.

3.4.5.3 Alarm and Trip Switches

3.4.5.3.1 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 shall be used. Mercury switches shall not be used.

3.4.5.3.2 Unless otherwise specified, electric switches that open (deenergize) to alarm and close (energize) to trip shall be furnished by the vendor.

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

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

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

3.4.5.4 Housings for Arcing-Type Switches

Particular attention is called to the requirements of 2.1.13 concerning the characteristics of housings for arcing-type switches outlined in the applicable codes.

3.4.6 VIBRATION AND POSITION DETECTORS

- 3.4.6.1 The purchaser will indicate on the data sheets whether noncontacting probes, velocity or acceleration transducers, and the corresponding monitors are required.
- 3.4.6.2 When specified, vibration and axial-position transducers and monitors shall be supplied, installed, and calibrated in accordance with API Standard 670.
- 3.4.6.3 When specified, velocity and acceleration transducers and monitors shall be supplied, installed, and calibrated in accordance with API Standard 678.

3.5 Piping and Appurtenances

3.5.1 GENERAL

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

3.5.1.2 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 2.4.

3.5.1.3 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.

3.5.1.4 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.

Table 3—Minimum Requirements for Piping Materials

System	Steam		Cooling Water		Lube Oil	
	≤75 pounds per square inch gauge	>75 pounds per square inch gauge	Standard (≤1 inch)	Optional	≤1 inch	≥1½ inches
	Pipe	Seamless*	Seamless*	—	ASTM A 120, Schedule 40, galvanized to ASTM A 153	—
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 ≤1½ 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 53, Grade B; ASTM A 106, Grade B; 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.

* Schedule 80 for diameters from ½ inch to 1½ inches; Schedule 40 for diameters 2 inches and larger.

^b Schedule 40 for a diameter of 1½ inches; Schedule 10 for diameters of 2 inches and larger.

^c ½-inch diameter × 0.065-inch wall, ¾-inch diameter × 0.095-inch wall, or 1-inch diameter × 0.109-inch wall.

3.5.1.5 The design of piping systems shall achieve the following:

- Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.
- Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.
- Installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access openings.
- Elimination of air pockets.

e. Complete drainage through low points without disassembly of piping.

3.5.1.6 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.

3.5.1.7 Pipe threads shall be taper threads in accordance with ASME B1.20.1. Flanges shall be in accordance with ANSI B16.5. For socket-welded construction, a 1/16-inch (1.6-millimeter) gap shall be left between the pipe end and the bottom of the socket.

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

3.5.1.9 Connections, piping, valves, and fittings that are 1 1/4, 2 1/2, 3 1/2, 5, 7, or 9 inches in size shall not be used.

3.5.1.10 The minimum size of any connection shall be 1/2 inch nominal pipe size.

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

3.5.2 OIL PIPING

3.5.2.1 Oil drains shall be sized to run no more than half full when flowing at a velocity of 1 foot per second (0.3 meter per second) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Drain lines shall slope downward, at least 1:50 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.

3.5.2.2 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.

3.6 Special Tools

3.6.1 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.

3.6.2 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.

3.7 Insulation and Jacketing

- 3.7.1 When specified, turbines shall be insulated and jacketed. The insulation and jacketing shall extend over all portions of the turbine casing that may reach a normal operating temperature of 165°F (74°C) or higher. Blanket-type insulation is an acceptable alternative to insulation and jacketing.

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

SECTION 4—INSPECTION AND TESTING

4.1 General

4.1.1 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 process.

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

4.1.3 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.

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

- 4.1.5 The purchaser will specify the extent of his participation in the inspection and testing.

4.1.5.1 When shop inspection and testing have been specified by the purchaser, the purchaser and the vendor shall coordinate manufacturing hold points and inspectors' visits.

4.1.5.2 *Witnessed* means that a hold shall be applied to the production schedule and that 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.

4.1.5.3 *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.)

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

4.2 Inspection

4.2.1 GENERAL

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

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

- 4.2.1.3 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.

4.2.2 MATERIAL INSPECTION

4.2.2.1 General

- ▶ 4.2.2.1.1 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.
- ▶ 4.2.2.1.2 When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 through 4.2.2.5 shall apply unless other criteria are specified by the purchaser. Cast iron may be inspected in accordance with 4.2.2.4 and 4.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 4.2.2.2 through 4.2.2.5.

4.2.2.2 Radiography

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

4.2.2.2.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-52, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

4.2.2.3 Ultrasonic Inspection

- 4.2.2.3.1 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.

4.2.2.3.2 Ultrasonic inspection shall be in accordance with Section V, Article 5, of the ASME Code.

4.2.2.3.3 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.

4.2.2.4 Magnetic Particle Inspection

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

4.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 6, 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.

4.2.2.5 Liquid Penetrant Inspection

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

4.2.2.5.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 8, of the ASME Code. The acceptance standard used

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

for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

Note: Regardless of these generalized limits, it shall be the vendor's responsibility to review the design limits of all castings in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in Table 4 shall be removed to meet the quality standards cited above, as determined by the inspection method specified.

4.2.3 MECHANICAL INSPECTION

4.2.3.1 During assembly of the system 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.

4.2.3.2 Any portion of the oil system furnished shall meet the cleanliness requirements of API Standard 614.

4.3 Testing

4.3.1 GENERAL

4.3.1.1 Equipment shall be tested in accordance with 4.3.2 and 4.3.3. Other tests that may be specified by the purchaser are described in 4.3.4.

4.3.1.2 The vendor shall notify the purchaser not less than 5 working days before the date the equipment will be ready for testing.

4.3.2 HYDROSTATIC TEST

4.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1½ times the maximum allowable working pressure but not less than 20 pounds per square inch gauge (1.4 bar gauge). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

4.3.2.2 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 room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room 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.

4.3.2.3 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.

4.3.2.4 The use of a sealant compound on the casing joints is acceptable during hydrotest.

4.3.3 MECHANICAL RUNNING TEST

4.3.3.1 The requirements of 4.3.3.1.1 through 4.3.3.1.9 shall be met before the mechanical running test is performed.

4.3.3.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

- 4.3.3.1.2 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 determined.

4.3.3.1.3 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.

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

4.3.3.1.5 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.

4.3.3.1.6 When purchased, job 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 and Standard 678 shall be used.

4.3.3.1.7 The vibration characteristics determined by the use of the instrumentation specified in 4.3.3.1.5 or 4.3.3.1.6 shall serve as the basis for acceptance or rejection of the machine (see 2.8.4.5 and 2.8.4.9).

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

4.3.3.1.9 All warning, protective, and control devices shall be checked, and adjustments shall be made as required.

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

4.3.3.3 Unless otherwise specified, the control system shall be demonstrated and the mechanical running test of the equipment shall be conducted as specified in 4.3.3.3.1 through 4.3.3.3.7.

4.3.3.3.1 Steam conditions shall be as close to normal as practical.

4.3.3.3.2 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 after lube-oil temperatures and shaft vibrations have stabilized.

4.3.3.3.3 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.

4.3.3.3.4 Vibration readings shall be taken at maximum continuous speed, just below trip speed, and at minimum operating speed after the stabilization described in 4.3.3.3.2. Maximum allowable vibration limits are described in 2.8.4.5 or 2.8.4.9 as applicable. Any critical speeds below maximum continuous shall be determined. Vibration limits for operation just below trip speed for turbines covered by 2.8.4.9 are 1.5 times the stated values.

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

4.3.3.3.6 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.

4.3.3.3.7 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.

4.3.3.4 Unless otherwise specified, the requirements of 4.3.3.4.1 through 4.3.3.4.3 shall be met after the mechanical running test is completed.

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

4.3.3.4.2 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.

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

• 4.3.4 OPTIONAL TESTS

The purchaser will specify in the inquiry or in the order if any of the shop tests specified in 4.3.4.1 through 4.3.4.5 shall be performed.

• 4.3.4.1 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.

• 4.3.4.2 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 specified by the purchaser.

• 4.3.4.3 Gear Test

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

4.3.4.4 Sound-Level Test

The sound-level test shall be performed in accordance with API Standard 615.

• 4.3.4.5 Auxiliary-Equipment Test

Auxiliary equipment such as oil systems, gears, 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.

4.4 Preparation for Shipment

4.4.1 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.

4.4.2 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.

4.4.3 The equipment shall be prepared for shipment after all testing and inspection has been completed. The preparation shall include that specified in 4.4.3.1 through 4.4.3.13.

4.4.3.1 Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint.

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

4.4.3.3 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.

4.4.3.4 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.

4.4.3.5 Flanged openings shall be provided with metal closures at least $\frac{3}{16}$ inch (4.8 millimeters) 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.

4.4.3.6 Threaded openings shall be provided with caps or round-head plugs in accordance with ANSI B16.11. The caps or plugs shall be made of material that is equal to or better than that of the pressure casing. In no case shall nonmetallic (such as plastic) caps or plugs be used.

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

4.4.3.8 Lifting points and lifting lugs shall be clearly identified.

4.4.3.9 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.

4.4.3.10 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 vapor-phase inhibitor. Suitable lead sheeting, at least $\frac{1}{8}$ inch (3.2 millimeters) thick, shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

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

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

4.4.3.13 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.

4.4.4 Components (both individual pieces and packaged sets) that are shipped with mounted preassembled piping, tubing, or wiring shall comply with the requirements of the Occupational Safety and Health Administration.

4.4.5 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.

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

SECTION 5—VENDOR'S DATA

5.1 Proposals

The vendor's proposal shall include the information listed in Items a through n below.

- a. A copy of the Vendor Drawing and Data Requirements form (see Appendix E) indicating the schedule according to which the vendor agrees to furnish the data requested by the purchaser (see 5.2).
- b. 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 specific list that details and explains each deviation.
- c. Copies of the purchaser's data sheets with complete vendor's information entered thereon.
- d. If specified, a performance curve of steam flow versus power for various hand valve settings when they are operated at normal speed and steam conditions.
- e. Utility requirements such as steam, water, electricity, and lube oil, including the quantity of lube oil required at the supply pressure, the heat load to be removed by the oil, and the driver ratings and net loads. (Approximate data shall be defined and clearly identified as such). This information shall be entered on the data sheets.
- f. Maximum shipping weight entered on the data sheets.
- g. A preliminary dimensional outline drawing that shows available locations of inlet and exhaust openings.
- h. A list of spare parts recommended for start-up and normal maintenance purposes. (The purchaser will specify any special requirements for long-term storage.)
- i. An itemized list of the special tools included in the offering. The vendor shall list any metric items included in the offering.
- j. An outline of all necessary special weather protection required by the turbine and its auxiliaries for start-up, operation, and idleness. The vendor shall list separately the protective items he proposes to furnish.
- k. Typical cross-sectional drawings and literature to fully describe details of the offerings.
- l. Schematic diagrams of the lube-oil system and gland-sealing system when furnished by the turbine vendor.
- m. Alarm and shutdown facilities (see 3.4.5.3.5).
- n. Lateral critical speed values (see 2.8.2.1).

5.2 Contract Data

5.2.1 GENERAL

5.2.1.1 The following paragraphs specify information to be furnished by the vendor. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix E), if received from the purchaser, to the address or addresses noted on the 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.

5.2.1.2 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 name and item number.
- d. The purchase order number.
- e. Any other identification specified in the purchase order.
- f. The vendor's identifying shop order number, serial number, or other reference required to identify return correspondence completely.

5.2.2 DRAWINGS

5.2.2.1 The purchaser will state in the inquiry and in the order the number of prints and/or reproduces required and the times within which they are to be submitted by the vendor (see 5.1, Item a).

5.2.2.2 The purchaser will promptly review the vendor's drawings when they are received; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the drawings have been reviewed, the vendor shall furnish certified copies in the quantity specified. Drawings shall be clearly legible and in accordance with ANSI Y14.2M.

5.2.2.3 The following information shall be provided on the drawings:

- a. The purchaser's order number (on every drawing).
- b. The purchaser's equipment item number (on every drawing).
- c. The vendor's shop order and/or serial number (on every drawing).

- d. The weight of each assembly, of the heaviest piece of equipment that must be handled for erection, and of significant items to be handled for maintenance.
- c. Principal dimensions, including those required for the purchaser's foundation, piping design, maintenance clearances, and dismantling clearances.
- f. The direction of rotation.
- g. The size, type, location, and identification of all the purchaser's connections, including vents, drains, lube oil, conduits, and instruments. (The vendor's plugged connections shall be identified.)
- h. When applicable, the make, size, and type of couplings, and the location and extent of coverage of the guards.
- i. A list of reference drawings, shown on the outline drawing, if applicable.
- j. A list of any special weather-protection and climatization features.
- k. Cold-alignment setting data for equipment furnished by the vendor. Data on expected thermal growth, including transient effects, shall be included.
- l. Complete information to permit adequate foundation design by the purchaser. This shall include but shall not be limited to the following:
 1. Grouting details.
 2. The size and location of foundation bolts.
 3. The weight distribution for each bolt/subsoleplate location.
- m. The location of the center of gravity and rigging provisions to permit removal of the top half of the casing, the rotor, and any subassemblies that weigh more than 300 pounds (136 kilograms).

5.2.2.4 The vendor shall supply schematic diagrams of each system in the vendor's scope of supply, as well as outline drawings and specifications for the components.

5.2.2.5 The vendor shall supply cross-sectional or assembly-type drawings for all equipment furnished, showing all parts, running fits, clearances, and balancing data required for erection or maintenance.

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

5.2.4 DATA

5.2.4.1 The vendor shall provide full information to enable completion of the data sheets, first for "as purchased" and then for "as built." This should be done by the vendor correcting and filling out the data sheets and submitting copies to the purchaser.

- 5.2.4.2 When specified, the vendor shall make the following information available to the purchaser:
 - a. The vendor's physical and chemical data from mill reports (or certification) of nodular iron or steel pressure parts and forgings.
 - b. Certified shop logs of the mechanical running test.
 - c. A record of shop test data (which the vendor shall maintain for at least 5 years after the date of shipment). When specified, the vendor shall submit certified copies of the test data to the purchaser before shipment.
 - d. *The required number of lateral critical and torsional analysis reports (which the vendor shall furnish no later than 3 months after the date of the order). The lateral critical speed analysis shall include but shall not be limited to the following:*
 1. A complete description of the method used to determine the critical speeds.
 2. A graphic display of the critical speeds versus the operating speeds.
 3. A graphic display of support stiffness and its effect on the critical speeds.
 4. A graphic display of the rotor response to the unbalance weight.
 5. A listing of journal static loads.
 6. A listing of the stiffness and damping coefficients used in the calculation.
 7. A description of the tilting-pad bearing geometry and configuration, including pad angle, pivot clearance, pad clearance, and preload.

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

 1. A complete description of the method used to determine the critical speed.
 2. A graphic display of the mass elastic system.
 3. A *table identifying the mass moment and torsional stiffness of each component identified in the mass elastic system.*
 4. A graphic display of exciting sources versus speed and frequency.
 5. A graphic display of torsional critical speeds and deflections (that is, a mode shape diagram).
 6. The thrust bearing stiffness and damping coefficients used.
 7. The effect of alternative couplings on the analysis.
 - e. The calculated rotor response reports.

- f. Optional test data and reports specified by the purchaser.
- g. Campbell and Goodman diagrams or their equivalents for the specified speed range.
- h. A record of all balance corrections in accordance with Appendix B.
- i. ASME pressure vessel fabrication data including the manufacturer's data report, rubbings of the code stamp, stress relief charts, and mill test reports.
- j. Electrical and mechanical runout report.
- k. As-built thrust-bearing, radial-bearing, and seal clearances provided by the vendor.

5.2.4.3 The vendor shall furnish a parts list for all equipment supplied. The list shall completely identify each part so that the purchaser may determine the interchangeability of the part with other equipment furnished by the same manufacturer. Standard purchased items shall be identified by the original manufacturer's name and part number.

5.2.4.4 No more than 5 days after the shipping date, the vendor shall furnish the required number of instruction manuals in accordance with 5.2.5 for the equipment and any auxiliaries and instruments provided by the vendor.

5.2.4.5 The vendor shall submit a supplementary list of spare parts other than those included in the original proposal. This supplementary list shall include recommended spare parts, cross-sectional or assembly-type drawings, parts numbers, materials, prices, and delivery times. Parts numbers shall identify each part for purposes of interchangeability. Standard purchased items shall be identified by the original manufacturer's numbers. The vendor shall forward this supplementary list to the purchaser promptly after receipt of the approved drawings and in time to permit order and delivery of parts before field start-up.

5.2.5 INSTALLATION AND INSTRUCTION MANUALS

5.2.5.1 All information required for proper installation design and actual installation that is not shown on the drawings shall be compiled in a single document. This information should be forwarded at a time mutually agreed upon in the order but not later than final-issue prints. It should contain information such as alignment or grouting procedures, utility specifications (including quantity), and all installation design data.

5.2.5.2 Manufacturers shall provide sufficient written instructions including referenced drawings to enable the purchaser to correctly install, operate, and maintain the complete equipment ordered. This information

shall be compiled in a manual or manuals with a cover sheet that contains section titles and a complete list of referenced and enclosed drawings identified by title and drawing number.

5.2.5.3 The manuals shall include legible drawings of the equipment furnished (typical drawings are acceptable), a parts list, and completed data sheets. They shall also include instructions covering installation, final tests and checks, start-up, shutdown, operating limits, and operating and maintenance procedures. The recommended clearances and maximum and minimum design clearances shall be clearly stated.

5.2.5.4 The manual containing operating and maintenance data shall be forwarded not later than 5 days after the shipping date. If required, the manual shall include a section that covers special instructions for operation at specified extreme environmental conditions, such as temperature. The manual shall include the information specified in Items a through g below:

- a. Instructions covering start-up, normal shutdown, emergency shutdown, operating limits, and routine operating procedures.
- b. A description of turbine construction features and the functioning of component parts of governing, lubrication, overspeed-protection, and steam-seal leak-off systems.
- c. Outline drawings, sectional drawings, schematic sketches, and illustrative sketches in sufficient detail to identify all parts and show clearly the operation of all equipment and components and the methods of inspection and repair. Standardized sectional drawings are acceptable only if they represent the actual construction of the turbine.
- d. Instructions for erection, piping, and alignment [including expected thermally induced shaft centerline movement between the position at 60°F (16°C) ambient temperature and that at normal operating steam temperature and pressure].
- e. A description of rigging procedures, methods of disassembly, repair, adjustment, and inspection, and reassembly of turbines and auxiliaries.
- f. Maintenance information including the following:
 1. The maximum and minimum labyrinth, packing, and bearing clearances.
 2. Instructions for measuring and adjusting cold clearances.
 3. The rotor-float allowance and axial clearance tolerances of the blades.
 4. The runout and concentricity tolerances on shafts, wheels, and thrust collars.

- g. Reassembly information that includes the following:
1. The bolting sequence and torque values for such items as casing bolting, internal bolting, and thrust-collar locknuts.
 2. The reassembly sequences together with required inspection checks.
 3. The adjustment procedures necessary to achieve required positions, clearances, float, and so forth.

4. The detailed procedures for a preoperational check, setting, and adjustment of the overspeed trip device, the trip valve, and the speed-governing valve.
5. The coupling installation procedure.

APPENDIX A—GENERAL-PURPOSE STEAM TURBINE DATA SHEETS

GENERAL-PURPOSE STEAM TURBINE DATA SHEET CUSTOMARY UNITS

PAGE 2 OF 3

JOB NO. _____ ITEM NO. _____

REVISION _____ DATE _____

BY _____

1	<input type="checkbox"/> MATERIALS			<input type="checkbox"/> ACCESSORY EQUIPMENT BY VENDOR		
2	HIGH PRESSURE CASING _____	GRADE _____	<input type="checkbox"/> REMOTE TRIP <input type="checkbox"/> SOLENOID <input type="checkbox"/> VACUUM BREAKER (3.4.2.9)			
3	EXHAUST CASING _____	GRADE _____	<input type="checkbox"/> STEAM SEALING SYSTEM (2.7.5) <input type="checkbox"/> AUTOMATIC GLAND VACUUM DEVICE WITH: (2.7.4)			
4	NOZZLES _____	GRADE _____	<input type="checkbox"/> WATER EDUCTOR <input type="checkbox"/> STEAM EJECTOR <input type="checkbox"/> GLAND CONDENSOR MOUNTED BY (2.7.4) _____			
5	BLADING _____	GRADE _____	<input type="checkbox"/> SENTINEL WARNING VALVE (3.4.5.2) <input type="checkbox"/> INSULATION (3.7.1), TYPE _____			
6	WHEELS _____	GRADE _____	<input type="checkbox"/> METAL INSULATION COVER <input type="checkbox"/> TACHOMETER (3.4.4.1), TYPE _____			
7	SHAFT _____	GRADE _____	MFR. _____ MODEL _____ MOUNTED BY _____			
8	<input type="checkbox"/> SHAFT COATING UNDER PACKING (2.6.2.3)		<input type="checkbox"/> OTHER SWITCHES AND CONTROL DEVICES BY VENDOR (3.4.5.1)			
9	MATERIAL _____					
10	APPLICATION METHOD _____					
11	THICKNESS _____					
12	GOV. VALVE TRIM _____					
13	INLET STRAINER _____ MESH SIZE _____					
14	GOVERNOR TYPE <input type="radio"/> OIL RELAY <input type="radio"/> HYDR. <input type="radio"/> OTHER _____					
15	NEMA CLASS _____					
16	SPEED CHANGER <input type="radio"/> MANUAL <input type="radio"/> PNEUM. <input type="radio"/> ELECT. (3.4.2.3)					
17	MFR. _____ MODEL _____					
18						
19						
20	CONTROLLED VARIABLE	OPERATING RANGE	CONTROL SIGNAL			
21	SPEED	_____ TO _____ RPM	_____ TO _____ PSIG/MA			
22		_____ TO _____ RPM	_____ TO _____ PSIG/MA			
23	<input type="checkbox"/> CONNECTIONS (2.4.1)					
24		SIZE	RATING	FACING	POSITION	MATING PARTS FURNISHED (2.4.5.5)
25	INLET					
26	EXHAUST					
27	DRAINS					
28						
29						
30						
31						
32	COUPLINGS (3.2) <input type="checkbox"/> SEE SEPARATE DATA SHEET					
33	MANUFACTURER	TURBINE	DRIVEN			
34	TYPE/SIZE					
35	LUBRICATION					
36	FURN. BY					
37	DRIVER HALF MOUNTED BY (3.2.1)					
38	DYN. BALANCE CL (3.2.8)					
39	<input type="radio"/> AGMA CLASS 8 <input type="radio"/> OTHER _____					
40	TURBINE SHAFT <input type="checkbox"/> TAPER <input type="checkbox"/> STRAIGHT <input type="checkbox"/> HYDRAULIC FIT HUB					
41						
42	<input type="checkbox"/> MOUNTING PLATES					
43	TYPE: (3.3.1.1) <input type="radio"/> BASEPLATE <input type="radio"/> SOLEPLATE (3.3.1.1)					
44	FURN. BY: <input type="radio"/> TURBINE VENDOR					
45	<input type="radio"/> DRIVEN EQUIPMENT VENDOR <input type="radio"/> OTHER _____					
46	EQUIPMENT TO BE MOUNTED: (3.3.2.1)					
47	<input type="radio"/> TURBINE <input type="radio"/> GENERATOR <input type="radio"/> GEAR					
48	<input type="radio"/> PUMP <input type="radio"/> OTHER _____					
49	<input type="radio"/> UNGROUTED BASEPLATE (3.3.2.6)					
50	<input type="radio"/> EPOXY GROUT (3.3.1.25)					
51	MOUNTING PLATE TO BE FURNISHED WITH:					
52	<input type="radio"/> DECKPLATE OVER ALL WALK AREAS (3.3.2.5)					
53	<input type="radio"/> SUBSOLE PLATES (3.3.2.3) <input type="radio"/> OTHER _____					
54						
			EXTERNAL LUBE OIL SYSTEM			
			<input type="checkbox"/> CIRCULATING (2.10.5) <input type="checkbox"/> PRESSURE (2.10.8)			
			VENDOR FURNISH SYSTEM FOR: <input type="radio"/> TURBINE			
			<input type="radio"/> OTHER _____			
			OIL SYSTEM TO BE: <input type="radio"/> CONSOLE TYPE			
			<input type="radio"/> MOUNTED ON BASEPLATE			
			OIL SYSTEM TO INCLUDE FOLLOWING EQUIPMENT: (2.10.5) (2.10.7)			
			<input type="checkbox"/> STANDBY OIL PUMP: TYPE DRIVER _____			
			<input type="checkbox"/> LOW OIL PRESS ALARM SWITCH			
			<input type="checkbox"/> LOW OIL PRESS TRIP SWITCH			
			<input type="checkbox"/> HEATER (2.10.8) <input type="radio"/> ELECTRIC <input type="radio"/> STEAM			
			<input type="checkbox"/> OIL DRAIN SIGHT FLOW INDICATORS			
			VIBRATION AND POSITION DETECTORS (3.4.5)			
			<input type="checkbox"/> FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING VIBRATION PROBES (2.9.21)			
			<input type="checkbox"/> FURN. AXIAL POSITION PROBES <input type="checkbox"/> NO. OF PROBES _____			
			<input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____			
			<input type="checkbox"/> FURN. RADIAL PROBES <input type="checkbox"/> NO. OF PROBES PER BEARING _____			
			<input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____			
			<input type="checkbox"/> FURN. VEL/ACC TRANSDUCERS <input type="checkbox"/> NO. PER BEARING _____			
			<input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____			
			VB. /AXIAL MONITORS: TURB. VENDOR DRIVEN EQUIP. VENDOR PURCHASER			
			FURNISHED BY: <input type="radio"/> <input type="radio"/> <input type="radio"/>			
			MOUNTED BY: <input type="radio"/> <input type="radio"/> <input type="radio"/>			
			<input type="checkbox"/> SEE SEPARATE DATA SHEETS FOR DETAILS			

GENERAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS

PAGE 1 OF 3

JOB NO. _____ ITEM NO. _____
 PURCH. ORDER NO. _____ DATE _____
 INQUIRY NO. _____ BY _____
 REVISION _____ DATE _____

1	APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input type="radio"/> AS BUILT				
2	FOR _____		UNIT _____		
3	SITE _____		NO. REQUIRED _____		
4	SERVICE _____		DRIVEN EQUIPMENT _____		
5	MANUFACTURER _____		MODEL _____ SERIAL NO. _____		
6	NOTE: <input type="radio"/> INDICATES INFORMATION COMPLETED BY PURCHASER <input type="checkbox"/> BY MANUFACTURER				
7	<input type="radio"/> OPERATING CONDITIONS			<input type="checkbox"/> PERFORMANCE	
8	OPERATING POINT	POWER, KW	SPEED, RPM	OPERATING POINT/STEAM CONDITION	NO. HAND VALVES OPEN (3.4.1.4)
9					
10	NORMAL			NORMAL/NORMAL (CERTIFIED SR)	
11	RATED			RATED/NORMAL	
12	OTHER (2.1.4)			RATED/MIN. INLET-MAX EXHAUST	
13	<input type="radio"/> DUTY, SITE AND UTILITY DATA			<input type="checkbox"/> APPLICABLE SPECIFICATION	
14	APPLICATION IS (SPARED, UNSPARD) _____			API-611 OTHER _____	
15	<input type="radio"/> SLOW ROLL REQ. (2.10.4) <input type="radio"/> HAND VALVES REQ. (3.4.1.4)				
16	DUTY <input type="radio"/> CONTINUOUS <input type="radio"/> STANDBY				
17	<input type="radio"/> UNATTENDED AUTO START (2.1.6)				
18	LOCATION (2.1.14) <input type="radio"/> INDOOR <input type="radio"/> HEATED <input type="radio"/> UNHEATED			<input type="checkbox"/> CONSTRUCTION	
19	<input type="radio"/> OUTDOOR <input type="radio"/> ROOF <input type="radio"/> WITHOUT ROOF			TURBINE TYPE <input type="radio"/> HORIZ <input type="radio"/> VERTICAL	
20	AMBIENT TEMP. °C MIN. _____ MAX. _____			NO STAGES _____ WHEEL DIA., mm _____	
21	UNUSUAL CONDITIONS (2.11.1.7) <input type="radio"/> DUST <input type="radio"/> SALT ATMOSPHERE			ROTOR: <input type="checkbox"/> BUILT UP <input type="checkbox"/> SOLID <input type="checkbox"/> OVERHUNG <input type="checkbox"/> BETWEEN BRGS	
22	<input type="radio"/> OTHER _____			BLADING <input type="checkbox"/> 2 ROW <input type="checkbox"/> 3 ROW <input type="checkbox"/> RE ENTRY	
23	ELECT. AREA (2.1.13) CLASS _____ GROUP _____ DIV _____			CASING SPLIT <input type="checkbox"/> AXIAL <input type="checkbox"/> RADIAL	
24	<input type="radio"/> NON-HAZARDOUS			CASING SUPPORT <input type="checkbox"/> CENTERLINE <input type="checkbox"/> FOOT	
25	CONTROL POWER V _____ PH. _____ HZ _____			<input type="radio"/> VERT. JACKSCREWS (2.1.16)	
26	AUX. MOTORS V _____ PH. _____ HZ _____			VERTICAL TURBINE FLANGE	
27	COOLING WATER: PRESS, BARG _____ Δ P, BAR _____			<input type="radio"/> NEMA "P" BASE <input type="radio"/> OTHER (2.4.9) _____	
28	FLOW, m ³ /hr _____ Δ T, °C _____			TRIP VALVE <input type="checkbox"/> INTEGRAL <input type="checkbox"/> SEPARATE	
29	ALLOW. SOUND PRESS LEVEL (2.1.12) _____ dBA @ _____ m			INTERSTAGE SEALS <input type="checkbox"/> LABYRINTH <input type="checkbox"/> CARBON	
30	<input type="radio"/> STEAM CONDITIONS			END SEALS <input type="checkbox"/> CARBON RING, NO/BOX _____	
31				<input type="checkbox"/> LABYRINTH <input type="checkbox"/> MATERIAL _____	
32				TYPE RADIAL BEARINGS (2.9.1) _____	
33	INLET PRESS. (BARG) (kPa G)	MAX	NORMAL	TYPE THRUST BEARING (2.9.2) _____	
34	INLET TEMP, °C			THRUST COLLAR (2.9.7.2) <input type="checkbox"/> REPLACABLE <input type="checkbox"/> INTEGRAL <input type="checkbox"/> NONE	
35	EXHAUST PRESS (BARG) (mmHg GA)			<input type="checkbox"/> LUBE OIL VISCOSITY (2.10.3) ISO GRADE _____	
36	<input type="radio"/> STEAM CONTAMINANTS (2.11.1.7)			LUBRICATION <input type="radio"/> RING OILED <input type="radio"/> PRESSURE <input type="radio"/> GREASE	
37	TURBINE DATA			OIL MIST (2.9.1.9)	
38	<input type="checkbox"/> ALLOW SPEEDS, RPM, MAX _____ MIN _____			<input type="radio"/> PURGE OIL MIST <input type="radio"/> PURE OIL MIST	
39	<input type="checkbox"/> MAX CONT SPEED, RPM (1.4.7) _____				
40	<input type="checkbox"/> TRIP SPEED, RPM _____ BLADE TIP VEL, mm/s _____				
41	<input type="checkbox"/> FIRST CRITICAL SPEED, RPM (2.8.2.1) _____				
42	<input type="checkbox"/> EXH. TEMP °C _____ NORMAL _____ NO LOAD _____				
43	<input type="checkbox"/> POTENTIAL MAX. POWER, KW (1.4.19) _____				
44	<input type="checkbox"/> MAX. NOZZLE STEAM FLOW, kg/hr _____				
45	ROTATION FACING GOVERNOR END <input type="radio"/> CCW <input type="radio"/> CW			CASINO DESIGN	
46	<input type="radio"/> DRIVEN EQUIPMENT THRUST, N (2.9.8) _____			INLET	
47	(VERTICAL TURBINE) (2.9.3)			EXHAUST	
48	<input type="radio"/> WATER PIPING FURN. BY <input type="radio"/> VENDOR <input type="radio"/> OTHERS			MAX. ALLOW. PRESS, BARG	
49	<input type="radio"/> OIL PIPING FURN. BY <input type="radio"/> VENDOR <input type="radio"/> OTHERS			MAX. ALLOW. TEMP, °C	
50				HYDRO TEST PRESSURE, BARG	

GENERAL-PURPOSE STEAM TURBINE DATA SHEET SI UNITS

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JOB NO. _____ ITEM NO. _____

REVISION _____ DATE _____

BY _____

<p><input type="checkbox"/> MATERIALS</p> <p>2 HIGH PRESSURE CASING _____ GRADE _____</p> <p>3 EXHAUST CASING _____ GRADE _____</p> <p>4 NOZZLES _____ GRADE _____</p> <p>5 BLADING _____ GRADE _____</p> <p>6 WHEELS _____ GRADE _____</p> <p>7 SHAFT _____ GRADE _____</p> <p>8 <input type="checkbox"/> SHAFT COATING UNDER PACKING (2.6.2.3)</p> <p>9 MATERIAL _____</p> <p>10 APPLICATION METHOD _____</p> <p>11 THICKNESS _____</p> <p>12 GOV. VALVE TRIM _____</p> <p>13 INLET STRAINER _____ MESH SIZE _____</p> <p>14 GOVERNOR TYPE <input type="radio"/> OIL RELAY <input type="radio"/> HYDR. <input type="radio"/> OTHER _____</p> <p>15 NEMA CLASS _____</p> <p>16 SPEED CHANGER <input type="radio"/> MANUAL <input type="radio"/> PNEUM. <input type="radio"/> ELECT. (3.4.2.3)</p> <p>17 MFR. _____ MODEL _____</p> <p>18 _____</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:25%;">CONTROLLED VARIABLE</th> <th style="width:25%;">OPERATING RANGE</th> <th style="width:25%;">CONTROL SIGNAL</th> </tr> <tr> <td>21 SPEED</td> <td>_____ TO _____ RPM</td> <td>_____ TO _____ BARG/ma</td> </tr> <tr> <td>22</td> <td>_____ TO _____ RPM</td> <td>_____ TO _____ BARG/ma</td> </tr> </table> <p>24 <input type="checkbox"/> CONNECTIONS (2.4.1)</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th>SIZE</th> <th>RATING</th> <th>FACING</th> <th>POSITION</th> <th>MATING PARTS FURNISHED (2.4.6.5)</th> </tr> <tr> <td>26 INLET</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>27 EXHAUST</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>28 DRAINS</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>29</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>30</td> <td></td> <td></td> <td></td> <td></td> </tr> </table> <p>32 COUPLINGS (3.2) <input type="radio"/> SEE SEPARATE DATA SHEET</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th>MANUFACTURER</th> <th>TURBINE</th> <th>DRIVEN</th> </tr> <tr> <td>33</td> <td></td> <td></td> </tr> <tr> <td>34 TYPE/SIZE</td> <td></td> <td></td> </tr> <tr> <td>36 LUBRICATION</td> <td></td> <td></td> </tr> <tr> <td>38 FURN. BY</td> <td></td> <td></td> </tr> <tr> <td>37 DRIVER HALF MOUNTED BY (3.2.1)</td> <td></td> <td></td> </tr> <tr> <td>38 DYN. BALANCE CL (3.2.6)</td> <td></td> <td></td> </tr> <tr> <td>39 <input type="radio"/> AGMA CLASS B <input type="radio"/> OTHER _____</td> <td></td> <td></td> </tr> <tr> <td>40 TURBINE SHAFT <input type="checkbox"/> TAPER <input type="checkbox"/> STRAIGHT <input type="checkbox"/> HYDRAULIC FIT HUB</td> <td></td> <td></td> </tr> </table> <p>42 <input type="radio"/> MOUNTING PLATES</p> <p>43 TYPE: (3.3.1.1) <input type="radio"/> BASEPLATE <input type="radio"/> SOLEPLATE (3.3.1.1)</p> <p>44 FURN. BY: <input type="radio"/> TURBINE VENDOR</p> <p>45 <input type="radio"/> DRIVEN EQUIPMENT VENDOR <input type="radio"/> OTHER _____</p> <p>46 EQUIPMENT TO BE MOUNTED: (3.3.2.1)</p> <p>47 <input type="radio"/> TURBINE <input type="radio"/> GENERATOR <input type="radio"/> GEAR</p> <p>48 <input type="radio"/> PUMP <input type="radio"/> OTHER _____</p> <p>49 <input type="radio"/> UNGROUTED BASEPLATE (3.3.2.6)</p> <p>50 <input type="radio"/> EPOXY GROUT (3.3.1.25)</p> <p>51 MOUNTING PLATE TO BE FURNISHED WITH:</p> <p>52 <input type="radio"/> DECKPLATE OVER ALL WALK AREAS (3.3.2.6)</p> <p>53 <input type="radio"/> SUBSOLE PLATES (3.3.2.3) <input type="radio"/> OTHER _____</p>	CONTROLLED VARIABLE	OPERATING RANGE	CONTROL SIGNAL	21 SPEED	_____ TO _____ RPM	_____ TO _____ BARG/ma	22	_____ TO _____ RPM	_____ TO _____ BARG/ma	SIZE	RATING	FACING	POSITION	MATING PARTS FURNISHED (2.4.6.5)	26 INLET					27 EXHAUST					28 DRAINS					29					30					MANUFACTURER	TURBINE	DRIVEN	33			34 TYPE/SIZE			36 LUBRICATION			38 FURN. 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AXIAL POSITION PROBES <input type="checkbox"/> NO. OF PROBES _____</p> <p><input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____</p> <p><input type="radio"/> FURN. RADIAL PROBES <input type="checkbox"/> NO. OF PROBES PER BEARING _____</p> <p><input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____</p> <p><input type="radio"/> FURN. VEL/ACC TRANSDUCERS <input type="checkbox"/> NO. PER BEARING _____</p> <p><input type="checkbox"/> MFR. _____ <input type="checkbox"/> MODEL _____</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th>VIB. AXIAL MONITORS:</th> <th>TURB. VENDOR</th> <th>DRIVEN EQUIP. VENDOR</th> <th>PURCHASER</th> </tr> <tr> <td>FURNISHED BY:</td> <td><input type="radio"/></td> <td><input type="radio"/></td> <td><input type="radio"/></td> </tr> <tr> <td>MOUNTED BY:</td> <td><input type="radio"/></td> <td><input type="radio"/></td> <td><input type="radio"/></td> </tr> </table> <p><input type="radio"/> SEE SEPARATE DATA SHEETS FOR DETAILS</p>	VIB. AXIAL MONITORS:	TURB. VENDOR	DRIVEN EQUIP. VENDOR	PURCHASER	FURNISHED BY:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	MOUNTED BY:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
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GENERAL-PURPOSE STEAM TURBINE DATA SHEET CUSTOMARY UNITS

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

ENGINEERING REQUIREMENTS	PREPARATION FOR SHIPMENT																																																																						
<p>1 <input type="radio"/> SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES (2.8.1.7)</p> <p>2 <input type="radio"/> CALCS AND/OR DATA FOR SEPARATION MARGIN (2.8.2.2)</p> <p>3 <input type="radio"/> TORSIONAL VIBRATION ANALYSIS (2.8.3.5)</p> <p>4 <input type="radio"/> WEIGHT OF HALF KEYS (2.8.4.2)</p> <p>5 <input type="radio"/> RESIDUAL UNBALANCE CHECK (2.8.4.3)</p> <p>6 <input type="radio"/> ELECTRICAL AND MECHANICAL RUNOUT (2.8.4.8)</p> <p>7 <input type="radio"/> HIGH SPEED GEARS, WHEN FURNISHED, SHALL CONFORM TO (3.1.3)</p> <p>8 <input type="radio"/> AP-677 <input type="radio"/> OTHER _____</p> <p>9 INTEGRAL GEAR TYPE: <input type="radio"/> SINGLE HELICAL</p> <p>10 <input type="radio"/> DOUBLE HELICAL <input type="radio"/> EPICYCLIC</p> <p>11 <input type="radio"/> SUBMIT CAMPBELL AND GOODMAN DIAGRAMS (5.2.4.2)</p> <p>12 REMARKS: _____</p> <p>13 _____</p> <p>14 _____</p> <p>15 _____</p> <p>16 _____</p> <p>17 _____</p> <p>18 _____</p>	<p style="text-align: center;"><input type="radio"/> PREPARATION FOR SHIPMENT</p> <p>TURBINE, AUX. EQUIPMENT AND SPARE ROTOR PREPARED FOR: (4.4.1)</p> <p><input type="radio"/> DOMESTIC SHIPMENT <input type="radio"/> EXPORT SHIPMENT</p> <p><input type="radio"/> TURBINE PREPARED FOR EXTENDED STORAGE _____ MONTHS</p> <p><input type="radio"/> SPARE ROTOR PREPARED FOR EXTENDED STORAGE _____ MONTHS (4.4.3.10)</p> <hr/> <p style="text-align: center;">TESTS (4.3) REQ'D. WITN. OBSVD. (4.1.4)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">HYDROSTATIC (4.3.2.1)</td> <td style="width: 10%; text-align: center;"><input type="radio"/></td> <td style="width: 10%; text-align: center;"><input type="radio"/></td> <td style="width: 10%; text-align: center;"><input type="radio"/></td> </tr> <tr> <td>MECH. RUN (4.3.3)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>BEARING OIL FLOW (4.3.3.1.2)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>PERFORMANCE (4.3.4.1)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>COMPLETE UNIT (4.3.4.2)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>GEAR (4.3.4.3)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>SOUND LEVEL (4.3.4.4)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>AUX. EQUIPMENT (4.3.4.5)</td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>REMARKS: _____</td> <td></td> <td></td> <td></td> </tr> </table> <hr/> <p style="text-align: center;">WEIGHTS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;"><input type="checkbox"/> TURBINE _____</td> <td style="width: 20%; text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> ROTOR _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> TURBINE UPPER HALF CASING _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> MAX MAINTENANCE (IDENTIFY) _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> T&T VALVE _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> BASEPLATE _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> MISC. _____</td> <td style="text-align: right;">LB</td> </tr> <tr> <td><input type="checkbox"/> TOTAL SHIPPING WEIGHT _____</td> <td style="text-align: right;">LB</td> </tr> </table> <p>REMARKS: _____</p> <p>_____</p>	HYDROSTATIC (4.3.2.1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	MECH. 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<p style="text-align: center;">INSPECTION REQUIREMENTS</p> <p>20 <input type="radio"/> 100% ULTRASONIC INSPECTION AFTER ROUGH MACHINING (4.2.2.3.1)</p> <p>21 <input type="radio"/> SPECIAL NDT INSPECTION OF FOLLOWING PARTS: (4.2.1.3)</p> <p>22 CASTING SURFACE INSPECTION <input type="radio"/> M38 SP-55 (4.2.2.1) <input type="radio"/> OTHER _____</p> <p>23 <input type="radio"/> WELD INSPECTION (4.2.2.1.2)</p> <p>24 SPECIAL INSPECTION (4.2.1.3) (4.2.2.1.2) (4.2.2.3.1)</p> <p>25</p> <table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th style="width: 10%;">COMPONENT</th> <th style="width: 10%;">MAG. PART.</th> <th style="width: 10%;">DYE PENET</th> <th style="width: 10%;">RADIO GRAPHIC</th> <th style="width: 10%;">ULTRA SONIC</th> <th style="width: 10%;">OBSVD</th> <th style="width: 10%;">WITN</th> </tr> </thead> <tbody> <tr> <td>26 T&T VALVE</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>27 STM CHEST</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>28 CASING</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>29 PIPING</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>30 ROTOR</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>31</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>32</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>33</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> <tr> <td>34</td> <td></td> <td></td> <td></td> <td></td> <td style="text-align: center;"><input type="radio"/></td> <td style="text-align: center;"><input type="radio"/></td> </tr> </tbody> </table>	COMPONENT	MAG. PART.	DYE PENET	RADIO GRAPHIC	ULTRA SONIC	OBSVD	WITN	26 T&T VALVE					<input type="radio"/>	<input type="radio"/>	27 STM CHEST					<input type="radio"/>	<input type="radio"/>	28 CASING					<input type="radio"/>	<input type="radio"/>	29 PIPING					<input type="radio"/>	<input type="radio"/>	30 ROTOR					<input type="radio"/>	<input type="radio"/>	31					<input type="radio"/>	<input type="radio"/>	32					<input type="radio"/>	<input type="radio"/>	33					<input type="radio"/>	<input type="radio"/>	34					<input type="radio"/>	<input type="radio"/>	<p style="text-align: center;">DATA REQUIREMENTS (5)</p> <p>36 <input type="radio"/> PROPOSAL FOR MULTI-STAGE UNITS TO INCLUDE CURVE OF STEAM FLOWS VS. POWER FOR VARIOUS HAND VALVE SETTINGS (5.1.4)</p> <p>37 <input type="radio"/> CONTRACT DATA TO INCLUDE PERFORMANCE CURVES FOR: (5.2.3)</p> <p>38 <input type="radio"/> STEAM FLOW VS. POWER</p> <p>39 <input type="radio"/> FIRST STAGE PRESSURE VS. STEAM FLOW</p> <p>40 REQUIRE CERTIFIED COPIES OF THE FOLLOWING:</p> <p>41 <input type="radio"/> MILL AND CHEMICAL DATA</p> <p>42 <input type="radio"/> SHOP TEST DATA</p> <p>43 <input type="radio"/> FINAL ASSEMBLY RECORDS (CLEARANCES)</p> <p>44 <input type="radio"/> CERTIFIED TEST DATA BEFORE SHIPMENT</p> <p>45 <input type="radio"/> ROTOR BALANCE CORRECTION</p> <p>46 <input type="radio"/> HYDROTEST</p> <p>47 REMARKS: _____</p> <p>48 _____</p> <p>49 _____</p> <p>50 _____</p> <p>51 _____</p> <p>52 _____</p> <p>53 _____</p> <p>54 _____</p>
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APPENDIX B—DAMPED UNBALANCED RESPONSE ANALYSIS

B.1 Lateral Analysis

B.1.1 When a damped unbalanced response analysis has been specified, the 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.
 - b. Changes in the stiffness and damping of bearing lubricant film and interstage clearance items resulting from speed, load, preload, lube-oil and steam 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).
- **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).

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 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:

$$L_v = \sqrt{\frac{12,000}{N}} \quad (\text{B-1})$$

In SI units, this translates to:

$$L_v = 25.4 \sqrt{\frac{12,000}{N}}$$

Where:

- L_v = vibration limit (amplitude of unfiltered vibration), in mils (micrometers) peak to peak.
 N = operating speed nearest the critical of concern in revolutions per minute.

This unbalance shall be no less than two times and no more than eight times the unbalance limit specified in 2.8.4. The unbalance weight or weights shall be placed at the location or locations within the bearing spar that have been analytically determined to affect the particular mode most adversely (for example, at midspan for translatory modes or near both ends and 180 degrees out of phase for conical modes). For bending modes that have maximum deflections at the shaft ends, the amount of unbalance shall be based on the overhung mass rather than the static bearing loading.

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. For the purposes of the verification test (see B.2), an additional plot of a test unbalance, as specified in Item b above (based on static bearing loading for rigid modes or overhung mass for bending modes), which shall be placed at a location determined by the vendor.
- e. When 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.

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:

$$SM = 100 - \left(84 + \frac{6}{AF - 3} \right)$$

d. If the amplification factor is greater than 3.55 and the critical response peak is above the trip speed, the required separation margin (a percentage of maximum continuous speed) is equal to the following:

$$SM = \left(126 - \frac{6}{AF - 3} \right) - 100$$

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.2 Shop Verification of Unbalanced Response Analysis

B.2.1 The criteria for confirming the validity of the damped unbalanced response analysis shall be the actual critical speed responses, as revealed on the test stand with a rotor unbalance magnitude in accordance with B.1.3, Item b, placed at a location (usually the coupling) determined by the vendor.

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.2.2 The parameters to be measured during the test shall be speed and shaft 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 amplitude of each response peak shall not exceed the

limits specified in B.1.5. The gain of the recording instrumentation 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 during the coast-down (deceleration) of the test unit.

Note 1: It is recognized that vectorial subtraction of slow-roll (300–600 revolutions per minute) total electrical and mechanical runout is always required for this verification and that vectorial subtraction of bearing-housing motion is normally required.

Note 2: 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 (1x) vibration signal. (When proximity probes are used, this is the lag angle between the vibration probe and the high spot on the rotor.)

Note 3: The major-axis amplitude is properly determined from a lissajous (orbit) display on an oscilloscope, oscillograph, or equivalent. When the phase angle between the x and y signals is not 90 degrees, the major-axis amplitude can be approximated by $(x^2 + y^2)^{1/2}$. 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.2.3 Additional testing will be required if, from the test data described above or a phase or amplitude indication in the damped unbalanced response analysis (based on the unbalance conditions described in B.1.3, Item b), it appears that either of the following conditions exists:

- Any critical response will fail to meet the separation margin requirements (see B.1.4) or will fall within the operating speed range.
- The requirements of B.1.5 have not been met.

B.2.4 Unbalance weights shall be placed as described in B.1.3, Item b. Unbalance magnitudes shall be achieved by adjusting the residual 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 not be 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 indicate the following acceptance criteria for the machine:

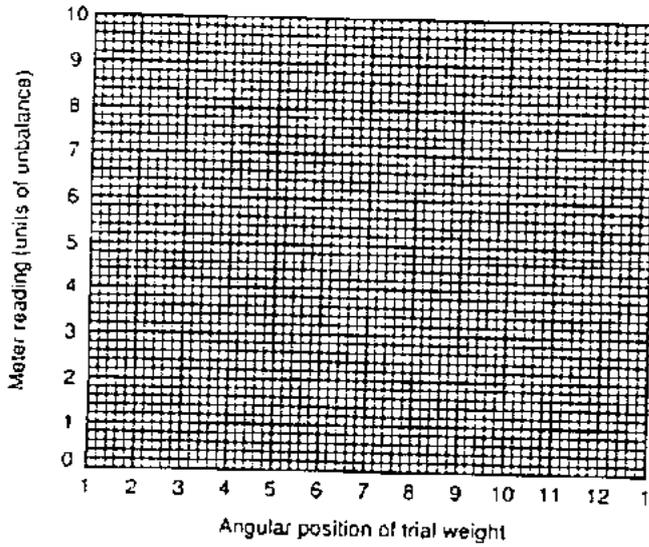
- At no speed within the operating speed range, including the separation margins, shall the shaft deflections exceed 55 percent of the minimum design running clearances or 150 percent of the allowable vibration limit at the probes (see B.1.3, Item b, and Figure 1).
- At all other speeds the shaft deflections shall not exceed 90 percent of the minimum design running clearances (see Figure 1).

The internal deflection limits specified in Items a and b above shall be based on the calculated displacement

APPENDIX C—RESIDUAL UNBALANCE WORK SHEET

Equipment Item No. _____

RESIDUAL UNBALANCE WORK SHEET



Right Plane

Half-key weights _____ oz. (g)
 Rotor speed (N) _____ rpm
 Journal static weight of rotor (W) _____ lb. (kg)
 Balance tolerance _____ oz.-in. (g-mm)
 (See note.)
 Trial weight ① _____ oz.-in. (g-mm)

$$\frac{\text{Max. reading} - \text{Min. reading}}{2} = \text{②} \text{ _____}$$

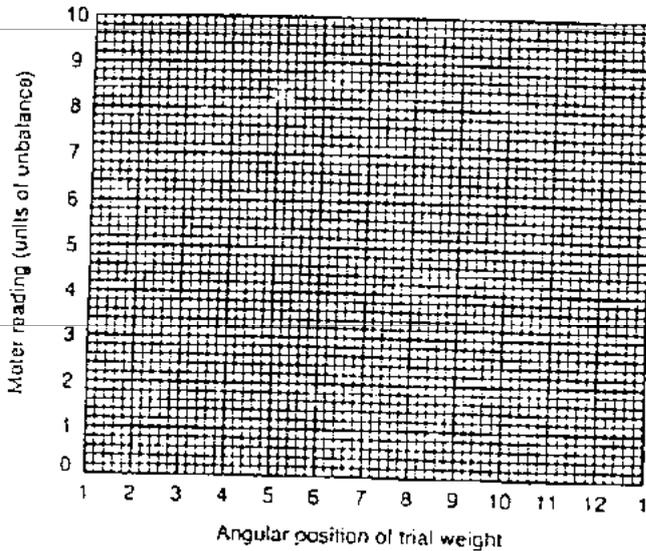
$$\frac{\text{Max. reading} + \text{Min. reading}}{2} = \text{①} \text{ _____}$$

 Residual unbalance =

$$\frac{\text{①} \times \text{②}}{\text{①}} = \text{_____ oz.-in. (g-mm)}$$

Note: If not specified, balance tolerance is the weight that produces 0.1 static loading at journal bearing when rotating at maximum continuous speed.

Witnessed _____



Left Plane

Half-key weights _____ oz. (g)
 Rotor speed (N) _____ rpm
 Journal static weight of rotor (W) _____ lb. (kg)
 Balance tolerance _____ oz.-in. (g-mm)
 (See note.)
 Trial weight ① _____ oz.-in. (g-mm)

$$\frac{\text{Max. reading} - \text{Min. reading}}{2} = \text{②} \text{ _____}$$

$$\frac{\text{Max. reading} + \text{Min. reading}}{2} = \text{①} \text{ _____}$$

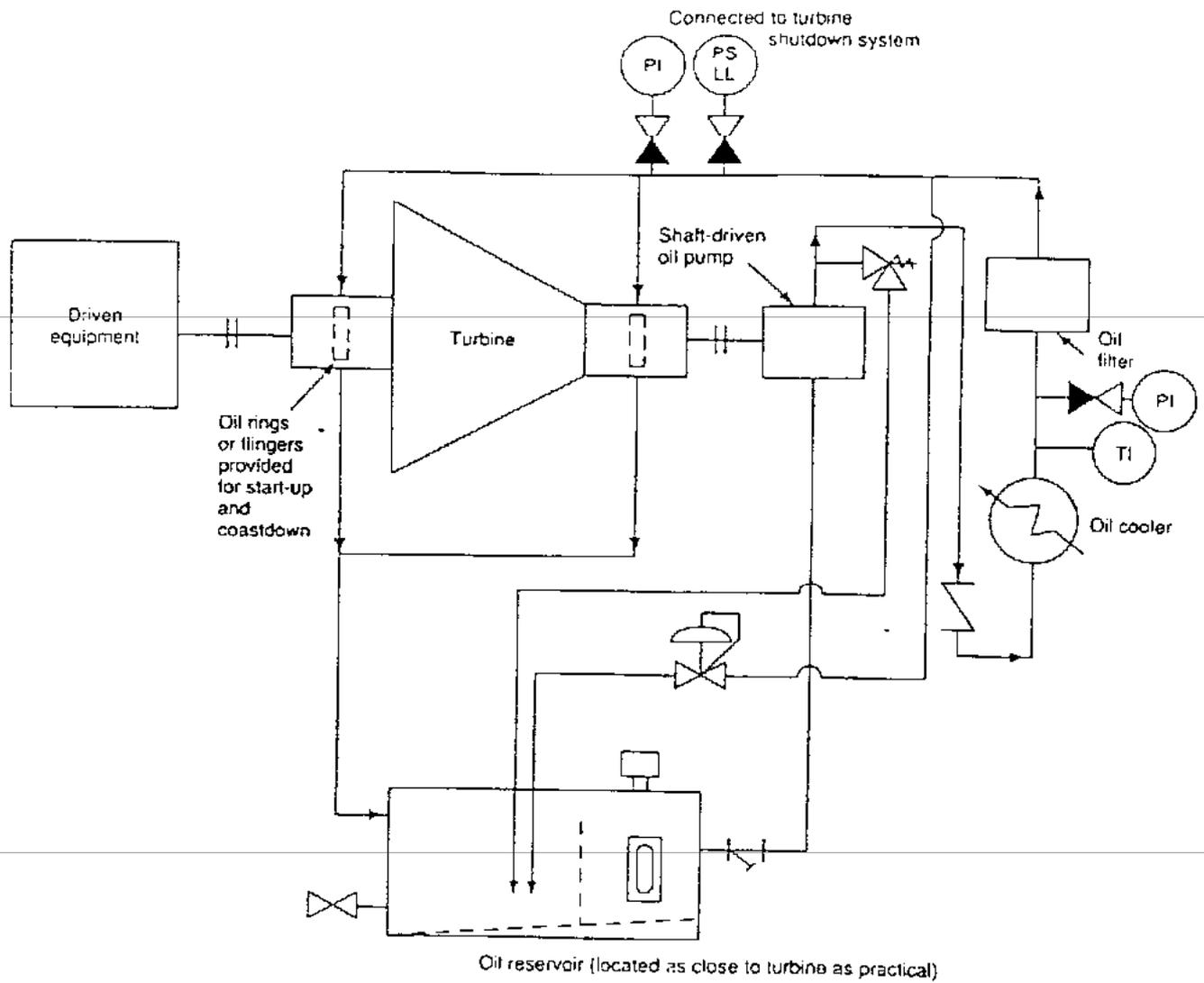
 Residual unbalance =

$$\frac{\text{①} \times \text{②}}{\text{①}} = \text{_____ oz.-in. (g-mm)}$$

Note: If not specified, balance tolerance is the weight that produces 0.1 static loading at journal bearing when rotating at maximum continuous speed.

Witnessed _____

APPENDIX D—MINIMUM PRESSURIZED LUBE-OIL SYSTEM



Abbreviations

- Ti temperature indicator
- PI pressure indicator
- PSLL low-pressure switch (shutdown)

Symbols

-  instrument (letters indicate function)
-  gate valve
-  relief valve
-  line strainer
-  pressure control valve
-  check valve
-  block-and-bleed valve

Note: This figure shows a typical schematic and does not constitute any specific design, nor does it include all required details (for example, vents and drains). This illustration is not necessarily adequate for all applications.

Figure D-1—Minimum Pressurized Lube-Oil System

APPENDIX E—VENDOR DRAWING AND DATA REQUIREMENTS

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.
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. Air or water 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.
 17. Steam flow versus horsepower curves at normal and rated speeds under normal steam conditions.

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 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 (80–105 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 60°F (15°C) 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. Instruction manuals describing installation, operation, and maintenance procedures. 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 drawing.

Note: Items 7, 11, 12, 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 5.2.5 in text of standard)