

# Gas Turbines for the Petroleum, Chemical, and Gas Industry Services

API STANDARD 616  
FOURTH EDITION, AUGUST 1998



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- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

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**Manufacturing, Distribution and Marketing Department**

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## FOREWORD

This standard is based on the accumulated knowledge and experience of manufacturers and users of gas turbines for the petroleum, chemical, and gas industry services. The objective of this publication is to provide a purchase specification to facilitate the manufacture and procurement of gas turbines for use in petroleum refinery services.

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 such modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or incorporating sections thereof 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.

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Suggested revisions are invited and should be submitted to the director of the Manufacturing, Distribution and Marketing 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 extreme 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 U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products, published at 54 Federal Register 29460 (July 12, 1989).

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 that 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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# Gas Turbines for the Petroleum, Chemical, and Gas Industry Services

## 1 Scope

This standard covers the minimum requirements for open, simple, and regenerative-cycle combustion gas turbine units for services of mechanical drive, generator drive, or process gas generation. All auxiliary equipment required for operating, starting, and controlling gas turbine units and for turbine protection is either discussed directly in this standard or referred to in this standard through references to other publications. Specifically, gas turbine units that are capable of continuous service firing gas or liquid fuel or both are covered by this standard.

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 ALTERNATIVE DESIGNS

The vendor may offer alternative designs.

### 1.2 CONFLICTS

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

## 2 References

### 2.1 REFERENCED STANDARDS

This standard includes references to the following API, industry, and government standards. The current edition of the referenced publications apply unless a specific edition is referenced.

#### API

Spec 5L	<i>Specification for Line Pipe</i>
MPMS	Chapter 15
RP 550	<i>Manual on Installation of Refinery Instruments and Control Systems</i>
Spec 5L	<i>Specification for Line Pipe</i>
Std 541	<i>Form-Wound Squirrel Cage Induction Motors—250 Horsepower and Larger</i>
Std 605	<i>Large-Diameter Carbon Steel Flanges (Nominal Pipe Sizes 26 through 60, Classes 75, 150, 300, 400, 600, and 900)</i>
Std 611	<i>General-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services</i>
Std 612	<i>Special-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services</i>
Std 613	<i>Special-Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services</i>

Std 614	<i>Lubrication, Shaft-Sealing, and Control Oil Systems for Special-Purpose Applications</i>
Std 670	<i>Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems</i>
Std 671	<i>Special-Purpose Couplings for Refinery Service</i>
RP 683	<i>Quality Improvement Manual for Mechanical Equipment in Petroleum, Chemical, and Gas Industries</i>

#### AFBMA<sup>1</sup>

Std 7	<i>Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans</i>
Std 9	<i>Load Ratings and Fatigue Life for Ball Bearings</i>
Std 11	<i>Load Ratings and Fatigue Life for Roller Bearings</i>
Std 20	<i>Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design; Basic Plan for Boundary Dimensions, Tolerances and Identification Code</i>

#### ANSI<sup>2</sup>

B16.11	<i>Forged Steel Fittings, Socket Welded and Threaded</i>
B92.1	<i>Involute Splines and Inspection</i>
B133.4	<i>Gas Turbine Control and Protection Systems</i>
B133.8	<i>Gas Turbine Installation Sound Emissions</i>

#### ASME<sup>3</sup>

B1.1	<i>Unified Inch Screw Threads (UN and UNR Thread Form)</i>
B1.20.1	<i>Pipe Threads, General Purpose (Inch)</i>
B16.1	<i>Cast Iron Pipe Flanges and Flanged Fittings</i>
B16.5	<i>Pipe Flanges and Flanged Fittings</i>
B16.42	<i>Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300</i>
B16.47	<i>Add Standard</i>
B31.3	<i>Chemical Plant and Petroleum Refinery Piping</i>
PTC 1	<i>General Instructions</i>

<sup>1</sup>Anti-Friction Bearing Manufacturers Association, 1101 Connecticut Avenue, N.W. Suite 700, Washington, D.C. 20036.

<sup>2</sup>American National Standards Institute, 1430 Broadway, New York, New York 10018.

<sup>3</sup>American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

PTC 22	<i>Gas Turbine Power Plants Boiler &amp; Pressure Vessel Code, Section V, "Nondestructive Examination"; Section VII, "Pressure Vessels"; and Section IX, "Welding and Brazing Qualifications"</i>	E 94	<i>Standard Guide for Radiographic Testing</i>
		E 165	<i>Standard Test Method for Liquid Penetrant Examination</i>
		E 709	<i>Standard Guide for Magnetic Particle Examination</i>
Y14.2M	<i>Line Conventions and Lettering Boiler and Pressure Vessel Code, Section VIII Performance Test Code 1, General Instructions Performance Test Code 22, Gas Turbine Power Plants</i>	AWS <sup>5</sup>	
		D1.1	<i>Structural Welding Code Steel</i>
ASTM <sup>4</sup>		IEEE <sup>6</sup>	
A 53	<i>Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated</i>	841	<i>Standard for Petroleum and Chemical Industry—Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors</i>
A 123	<i>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</i>	ISO <sup>7</sup>	
A 193	<i>Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service</i>	ISO-2314	<i>Gas Turbines—Acceptance Tests</i>
A 194M	<i>Standard Specification Temperature for Carbon and Alloy Nuts for Bolts for High-Temperature and High-Pressure Service</i>	ISO-3448	<i>Industrial Liquid Lubricants—ISO Viscosity Classification</i>
A 247	<i>Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings</i>	ISO-10494	<i>Gas Turbines and Gas Turbine Sets—Measurement of Emitted Airborne Noise—Engineering/Survey Method</i>
A 278	<i>Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650 Degrees F</i>	NACE <sup>8</sup>	
A 307	<i>Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength</i>	The NACE Corrosion Engineer's Handbook	
A 320	<i>Standard Specification for Alloy Steel Bolting Materials for Low-Temperature Service</i>	NFPA <sup>9</sup>	
A 388	<i>Standard Practice for Ultrasonic Examination of Heavy Steel Forgings</i>	12	<i>Standard on Carbon Dioxide Extinguishing Systems</i>
A 395	<i>Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures</i>	70	<i>National Electrical Code</i>
A 515	<i>Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Pressure Service</i>	72E	<i>National Fire Alarm Code Errata</i>
A 536	<i>Standard Specification for Ductile Iron Castings</i>	2001	<i>Standard on Clean Agent Fire Extinguishing Systems</i>
A 578	<i>Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications</i>	SSPC <sup>10</sup>	
A 609	<i>Standard Practice for Castings, Carbon, Low-Allow, and Martensitic Stainless Steel, Ultrasonic Examination Thereof</i>	SP 6	<i>Surface Preparation Specification No. 6, Commercial Blast Cleaning</i>
D 1655	<i>Standard Specification for Aviation Turbine Fuels</i>		
D 2880	<i>Standard Specification for Gas Turbine Fuel Oils</i>		

## 2.2 COMPLIANCE

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

<sup>5</sup>American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33135.

<sup>6</sup>Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, New York 10017-2394

<sup>7</sup>International Organization for Standardization. ISO publications are available from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

<sup>8</sup>National Association of Corrosion Engineers, P.O. Box 218340, Houston, Texas 77218.

<sup>9</sup>National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.

<sup>10</sup>Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213-2683

<sup>4</sup>American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.

## 2.3 RESPONSIBILITIES

The vendor bearing unit responsibility shall invoke all applicable specifications to each subvendor.

## 2.4 UNIT CONVERSION

The factors in Chapter 15 of the *API Manual of Petroleum Measurement Standards* were used to convert from U.S. Customary to SI units. The resulting exact SI units were then rounded off.

## 3 Definitions

For the purposes of this standard the following definitions apply:

**3.1 alarm point:** A pre-set value of a measured parameter at which an alarm is actuated to warn of a condition that requires corrective action.

**3.2 axially split:** A joint that is parallel to the shaft centerline.

**3.3 blade lock-up speed:** The speed of rotation at which a part span or tip damping device (whether joining all or multiple numbers of individual blades) becomes effective.

**3.4 blades:** Rotating airfoils for both compressors and turbines unless modified by an adjective.

**3.5 critical speed:** Refer to 4.7.1.

**3.6 design:** A term that may be used by the equipment manufacturer to describe various parameters such as design pressure, design temperature, or design speed.

Note: This terminology should be used only by the equipment manufacturer and not in the purchasers' specifications.

**3.7 filter stage:** A section of a filter system which is designed to remove specific site contaminants at a prescribed efficiency and pressure drop. A stage may be a specific medium, an inertial separator, a mist eliminator, or a self-cleaning section. *Multistage filters* are combinations of various filters. Weatherhoods and screens are not considered stages.

**3.8 flat rating:** The practice of limiting the gas turbine engine power to a constant power level over the entire site operating ambient temperature range.

Note: Flat rating of an engine permits the engine to operate at higher ambient temperature at an increased firing temperature and at lower ambient temperatures operate by reducing the firing temperature. The overall effect of the higher firing temperature on the life of engine hot parts is thereby reduced.

**3.9 gauge board:** A bracket or plate used to support and display gauges, switches, and other instruments. A gauge board is open and not enclosed.

**3.10 heat rate:** The energy consumption of a prime mover per unit of output work. For gas turbines, the heat rate is calculated on the basis of the lower heating value of the fuel.

**3.11 gas generators:** Devices in which only energy required to drive the compressor stages and auxiliaries is extracted from the discharging gas by the turbine stages.

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

**3.13 informative:** An appendix of the standards which is provided for information and is intended to assist the understanding or use of the standard. Compliance with an informative appendix is not mandated.

**3.14 inlet volume flow:** The flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility, and gas composition, including moisture content at the compressor inlet flange.

**3.15 ISO-rated cycle temperature:** The vendor's stated (calculated) turbine inlet total temperature, immediately upstream of the first stage turbine rotor blades, for continuous service at ISO-rated power output.

**3.16 ISO-rated firing temperature:** The vendor's stated (calculated) turbine inlet total temperature, immediately upstream of the first stage turbine nozzles, for continuous service at ISO-rated power output.

**3.17 ISO-rated power:** The continuous power developed by the gas turbine when it is operated at ISO-rated firing temperature and speed under the following standard operating conditions (see ISO-2314):

Inlet temperature	15°C (59°F)
Inlet (total) pressure	1.0133 bar (14.696 psia)
Inlet relative humidity	60 percent
Exhaust (static) pressure	1.0133 bar (14.696 psia)

This power and speed is measured at the output shaft of the gas turbine ahead of any separate gear or piece of driven equipment, except for the power output of electric generator drives. Rated power for electric generator drives shall be measured at the electrical output terminals of the generator. The inlet conditions shall be measured at the exhaust flange. These measuring locations shall be used for all power and gas flow measurements. The ISO rating provides only general sizing information and should not be confused with site rated power.

**3.18 local:** The position of a device when mounted on or near the equipment or console.

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

Note: The maximum allowable speed is usually set by rotor stress values.

**3.20 maximum allowable temperature:** The maximum continuous temperature for which the manufacturer has

designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

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

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

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

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

**3.25 minimum allowable temperature:** The lowest temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

**3.26 normal operating point:** The point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies that the heat rate is within the tolerances stated in this standard. Parameters used to determine the normal operating point include speed, site, conditions, emissions, and fuel composition.

**3.27 normally open and normally closed:** Refer both to on-the-shelf state and to the installed de-energized state of devices such as automatically controlled electric switches and valves.

Note: The normal operating condition of such a device is not necessarily the same as the device's on-the-shelf positions.

**3.28 normative:** A requirement of the standard.

Note: All reference standards are normative.

**3.29 nozzles (fixed and variable):** Turbine stationary airfoils.

**3.30 open cycle:** One which the working medium enters the gas turbine from the atmosphere and discharges to the atmosphere either directly or indirectly through exhaust heat recovery equipment. When the working medium passes successively through the compressor, the combustor, and the turbine, it is called a *simple cycle*; when turbine exhaust is used to preheat (by exchange) combustion air from the compressor, it is called a *regenerative cycle*.

**3.31 owner:** The final recipient of the equipment, who may delegate another agent as the purchaser of the equipment.

**3.32 panel:** An enclosure used to mount, display, and protect gauges, switches, and other instruments.

**3.33 potential maximum power:** The expected power capability when the gas turbine is operated at maximum allowable firing temperature, rated speed, or under other limiting conditions as defined by the manufacturer and within the range of specified site values.

**3.34 power turbine:** A turbine having a separate shaft from which output power is derived.

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

**3.36 purchaser:** The individual or organization that issues the order and specification to the vendor.

**3.37 radially split:** A joint which is perpendicular to the shaft centerline.

**3.38 rated speed:** The speed (revolutions per minute) of the gas turbine output shaft at which site rated power is developed.

**3.39 relief value set pressure:** The pressure at which a relief valve starts to lift.

**3.40 remote:** The position of a device when located away from the equipment or console, typically in a control house.

**3.41 shutdown point:** A preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

**3.42 site rated conditions:** The specified values at the inlet flange of the gas generator with maximum inlet air temperature, minimum inlet air pressure, and maximum exhaust pressure at which site rated power is required. Inlet and exhaust ducting and other facilities, barometric variations, and ambient temperature ranges shall be considered when specifying the site rated conditions.

**3.43 site rated cycle temperature:** The turbine inlet total temperature, immediately upstream of the first-stage turbine rotor blades, required to meet site rated power.

**3.44 site rated firing temperature:** The turbine inlet total temperature, measured at a location immediately upstream of the first-stage turbine nozzles, required to meet site rated power conditions.

**3.45 site rated power:** The shaft power developed by the gas turbine when it is operated at site rated firing temperature, rated speed, and site rated conditions of inlet temperature, inlet pressure, exhaust pressure, and normal fuel composition.

**3.46 standard flow:** The flow rate expressed in volume flow units at standard conditions as follows:

a. ISO Standard Conditions:

Flow: Cubic meters per hour  
m<sup>3</sup>/h  
cubic meters per minute  
m<sup>3</sup>/min

Pressure: 1.013 bar

Temperature: °C

b. U.S. Standard Conditions:

Flow: Standard cubic feet per minute  
scfm  
Million standard cubic feet per day  
mmscfd

Pressure: 14.7 psi

Temperature: 60°F

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

**3.48 thermal efficiency:** The ratio of the energy output at the power turbine shaft (or generator terminals) to the energy input (based on the lower heating value of the fuel) expressed in the same units. (External auxiliaries not directly driven are not included in parasitic losses.)

**3.49 total indicated reading (TIR), also known as total indicator runout:** The difference between the maximum and minimum readings of a dial indicator or similar device monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

Note: For a perfectly cylindrical surface the indicator reading gives an eccentricity equal to half the reading. For a perfectly flat face the indicator reading gives an out-of-squareness equal to the reading. If the diameter in question is not perfectly cylindrical or flat, interpretation of the meaning of TIR is more complex and may represent ovality or lobing.

**3.50 turbine trip speed:** The speed (in revolutions per minute) at which the independent emergency overspeed device shuts off fuel to the gas turbine.

**3.51 unit responsibility:** The responsibility for coordinating the technical aspects of the equipment and auxiliary systems included in the scope of the order. The technical aspects to be considered include but are not limited to such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications, and testing of components.

**3.52 vanes (fixed and variable):** Compressor stationary airfoils.

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

**3.54** 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.

## 4 Basic Design

### 4.1 GENERAL

**4.1.1** The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. It is recognized that this is a design criterion and that hot section inspections may be required; however, the required time between inspections shall be no less than 8000 operating hours.

**4.1.2** Unless otherwise specified, the gas turbine vendor shall assume unit responsibility.

- **4.1.3** The purchaser will specify the equipment’s normal operating point on the data sheets (see 3.26).

**4.1.4** Gas turbine units shall be suitable for idle periods of up to 3 weeks, under specified site conditions, without requiring any special maintenance procedures.

- **4.1.5** The output-shaft operating speed range of gas turbine units for mechanical-drive applications shall be as specified on the data sheets. Where only one operating speed is specified for an application, the speed range for single shaft machines shall be 25 percent (from 80 to 105 percent of rated speed), and the speed range for two or more shaft machines shall be 55 percent (from 50 to 105 percent of rated speed).

**4.1.6** Gas turbine units shall be designed for continuous service at each point of the specified speed range and power range including potential maximum power. Also, the vendor shall define the period between major overhauls while operating at potential maximum power.

**4.1.7** The turbine design shall accommodate transient thermal gradients following tripouts and shall permit immediate restarting subject to the driven equipment restrictions. Cold-start and hot-start restrictions shall be defined in the proposal. The purchaser shall agree with the vendor on consequences if the restrictions must be exceeded.

- **4.1.8** The purchaser will specify the maximum allowable emissions levels at the package boundaries. The control of exhaust emissions levels of the package shall be a joint effort of the gas turbine vendor and the purchaser. It is the responsibility of the purchaser to obtain any permits that may be required to operate the equipment and it is the responsibility of the gas turbine vendor to support the purchaser with emissions data.

The gas turbine vendor shall state in his proposal expected emissions levels consistent with the purchaser’s specified fuel properties and site operating conditions. The gas turbine vendor shall supply, if required, the turbine combustion emission suppression system to meet the specified levels of NO<sub>x</sub>, CO, and unburned hydrocarbons in the turbine’s exhaust gas.

- **4.1.9** When specified, the gas turbine unit shall be designed to permit steam or water injection for either increasing the unit's power capability or controlling emissions. The effects (for example, maintenance recommendations and parts replacement) of steam or water injection shall be stated in the proposal. The vendor shall specify the required quantity and quality of injection fluids.

- **4.1.10** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified by the purchaser.

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

- 4.1.11** A cooling water system or systems shall be designed for the following conditions:

Water velocity over heat exchange surfaces	1.5–2.5 m/s	5–8 ft/s
Maximum allowable working pressure	≥7.0 bar (Note 2)	≥100 psig
Hydrotest pressure (1.5 x MAWP)	≥10.4 bar (Note 2)	≥150 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30°C	90°F
Maximum outlet temperature	50°C	120°F
Maximum temperature rise	20°K	30°F
Minimum temperature rise	10°K	20°F
Fouling factor on water side	0.35 m <sup>3</sup> K/Kw	0.002 hr-ft <sup>2</sup> -F/Btu
Water side corrosion allowance	3 mm	1/8 in

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

Note 1: The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimize water side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. If such a conflict exists, the purchaser will approve the final selection.

Note 2: Gauge pressure.

- 4.1.12** Equipment shall be designed to run without damage at any speed up to the highest trip speed in combination with any specific level of allowable temperature identified by the vendor.

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

- **4.1.14** Motors, electrical components, and electrical installations shall be suitable for the area classification specified (class, group, and division or zone) by the purchaser, and

shall meet the requirements of NFPA 70, Articles 500, 501, 502, and 504, as well as local codes specified and furnished by the purchaser.

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

- 4.1.16** 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. Vanes and nozzles, seals, and rotating elements shall be replaceable on site. The vendor's proposal shall describe the special tooling needed for on-site replacement, and if the design does not permit it, the vendor shall state in the proposal the procedure for the field disassembly required for such repairs.

- 4.1.17** The turbine and its driven equipment shall perform on the test stand and on their 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 that has unit responsibility.

- **4.1.18** Many factors (such as piping and duct loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings. When specified, the vendors representative shall:

- Observe a check of the major piping connections by parting the flanges.
- Check alignment at the operating temperature.
- Witness the initial alignment check.

- **4.1.19** 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 and dust, or corrosive conditions). The unit and its auxiliaries shall be suitable for shipment, installation, and operation under these specified conditions.

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

- 4.1.21** The gas turbine shall be designed to provide site rated power with no negative tolerance.

- **4.1.22** The purchaser will specify bleed air requirements.

## 4.2 PRESSURE CASINGS

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

**4.2.2** All pressure parts shall be suitable for operation at the most severe coincident condition of pressure and temperature.

**4.2.3** Either radially or axially split casings are acceptable depending on the vendor's standard. The vendor's proposal shall clearly show the extent of component removal required for site maintenance. All casing joints, except inlet and exhaust flange connections, shall be metal fits without gaskets. All casing joints shall be tight at operating pressure and temperature with no perceptible leakage.

**4.2.4** Casings, supports, and baseplates shall be designed to prevent any injurious distortion that could be caused by the worst combination of allowable temperature, pressure, torque, and external forces and moments. Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews. The unit design shall also minimize the output shaft displacement between hot and cold positions.

**4.2.5** The use of tapped holes in pressure parts shall be held to a minimum. Sufficient metal in addition to the allowance for corrosion shall be left below the bottom of drilled and tapped holes to prevent leakage.

**4.2.6** Bolting shall be furnished as specified in 4.2.6.1 through 4.2.6.4.

**4.2.6.1** The details of threading shall conform to ASME B1.1.

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

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

**4.2.6.4** Stud ASTM grade marking shall be located on the nut end of the exposed stud.

**4.2.7** Openings for inspection instruments such as boroscopes shall be provided to permit complete inspection of all rotating gas-path components without disassembly.

**4.2.8** Jackscrews, guide rods, and cylindrical casing-alignment dowels shall be provided to facilitate disassembly and reassembly. When jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counter-bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or studs by the casing during disassembly and reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of each casing.

**4.2.9** For manufacturers unable to comply with the full speed testing requirements of this standard, the ducting and casing design shall permit field balancing in the end planes of the rotors without requiring the removal of major casing components.

**4.2.10** The casing design shall minimize disassembly of equipment for maintenance of the combustor system.

**4.2.11** Equipment feet that require adjustment for field alignment shall be provided with vertical jackscrews and drilled with pilot holes that are accessible for use in final doweling.

## 4.3 COMBUSTORS AND FUEL NOZZLES

**4.3.1** All combustor systems shall be provided with dual ignition. Combustor systems without cross-ignition tubes shall be provided with two igniters in each combustor. A single-combustor system shall have a pilot fuel system with ignitor ignition.

**4.3.2** The design of the combustors and transition pieces shall provide control of circumferential and radial gas temperature distribution such that the hot-gas-path components meet their slated life requirements. The vendor shall state in his proposal the maximum permissible temperature variation in the plane of measurement and shall define the plane. In no case shall gas temperatures exceed the turbine overtemperature limit specified by the vendor. There shall be a minimum of one temperature sensor per combustor for multicomburnator machines and no less than six temperature sensors per machine.

**4.3.3** Fuel nozzles shall be removable without dismantling of the combustors. For liquid fuels, nozzles shall be designed to operate without erosion, plugging, and carbonization which would require service attention between scheduled maintenance intervals. Combustors and fuel nozzles shall be designed and calibrated to permit random exchange of new nozzles without the need for field calibration and adjustment of flow or pressure drop.

**4.3.4** When dual fuel nozzles are used, the vendor shall describe in the proposal any requirement for continuous purging and cooling of the idle nozzles.

**4.3.5** Igniters shall not remain in the primary combustion zone during operation.

**4.3.6** Provision shall be made for inspection of the combustor system components. The vendor's proposal shall detail any disassembly and special equipment required to accomplish the inspection.

- **4.3.7** When specified, the manufacturer shall indicate the flexibility in the proposed combustion system by advising maximum and minimum Wobbe index limits of the combustion system.

## 4.4 CASING CONNECTIONS

- **4.4.1** Air inlet and exhaust connections of the pressure casings shall be flanged or machined and studded, oriented as specified and suitable for the positive or negative working pressure of the casing as defined in 3.21.
- 4.4.2** Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping (see 4.10.4.6).
- 4.4.3** Casing openings for piping connections shall be at least DN 20 ( $\frac{3}{4}$  inch NPS) and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes DN 20 ( $\frac{3}{4}$  inch NPS) through DN 40 ( $1\frac{1}{2}$  inch NPS) are permissible. The pipe nipples installed in the threaded openings shall be as specified in 4.4.3.1 through 4.4.3.5.
  - 4.4.3.1** A pipe nipple shall not be more than 150 millimeters (6 inches) long.
  - 4.4.3.2** The pipe nipple shall be a minimum of Schedule 160 seamless for sizes DN 25 (1 inch NPS) and smaller and a minimum of Schedule 80 for sizes DN 40 ( $1\frac{1}{2}$  inch NPS) and larger.
  - 4.4.3.3** The pipe nipple shall be provided with a welding-neck or socket-weld flange.
  - 4.4.3.4** The nipple and flange materials shall meet the requirements of 4.4.2.
  - 4.4.3.5** Threaded openings and bosses for tapered pipe threads shall conform to ANSI/ASME B16.5.
- 4.4.4** Tapped openings, in ferrous casings not connected to piping, shall be plugged with solid, steel plugs furnished in accordance with ASME B16.11. As a minimum, these plugs shall meet the material compatibility and strength requirements of the casing. Plugs that may later require removal shall be of corrosion resistant material. Lubricant of the proper temperature specification shall be used on all threaded connections. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.
- 4.4.5** Flanges shall conform to ASME B16.1, B16.5, or B16.42 as applicable, except as specified in 4.4.5.1 through 4.4.5.4.
  - 4.4.5.1** Cast iron flanges shall be flat faced and shall have a minimum thickness of Class 250 per ASME B16.1 for sizes 8 inches and smaller.
  - 4.4.5.2** Flat-faced flanges with full raised-face thickness are acceptable on casings other than cast iron.
  - 4.4.5.3** Flanges that are thicker or have a larger outside diameter than that required by ASME B16.5 or B16.47 are acceptable.

- **4.4.5.4** Connections other than those covered by ASME B16.5 or B16.47 require the purchaser's approval. Unless otherwise specified, mating parts for these nonstandard flanges shall be furnished by the vendor.

**4.4.6** Machined and studded connections shall conform to the facing and drilling requirements of ASME B16.1, B16.5, or B16.42. Studs and nuts shall be furnished installed. The first  $1\frac{1}{2}$  threads at both ends of each stud shall be removed. Connections larger than those covered by ASME shall meet the requirements of 4.4.5.4.

**4.4.7** All of the purchaser's connections shall be accessible for disassembly without the machine being moved.

## 4.5 ROTATING ELEMENTS

### 4.5.1 Shafts

**4.5.1.1** Shafts shall be designed and manufactured with the capability to transmit the maximum torque that can be developed at any steady state or transient condition in the total operating envelope. The envelope is as defined by the manufacturer within the range of specified site values.

**4.5.1.2** Shafts shall be made of one-piece heat treated steel that is suitably machined. Shafts that have a finished diameter larger than 200 millimeters (8 inches) shall be forged steel. Shafts that have a finished diameter of 200 millimeters (8 inches) or less shall be forged steel or, with the purchaser's approval, hot rolled bar-stock, provided such bar-stock meets all quality and heat treatment criteria established for shaft forgings.

**4.5.1.3** Load shaft ends shall conform to API Standard 671. Shafts with splined shaft ends shall conform to ANSI B92.1-1970. Shaft end integral hubs are also acceptable.

**4.5.1.4** When shaft radial vibration and/or axial-position probes are furnished, the rotor 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 key-way, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 1.0 micrometer (32 microinches)  $R_a$ , preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API Standard 670 or otherwise treated so that the combined total electrical and mechanical runout, relative to the journals, does not exceed 25 percent of the maximum allowed peak-to-peak vibration amplitude or the following value, whichever is greater:

- a. For areas to be observed by radial-vibration probes, 5 micrometers (0.25 mil).
- b. For areas to be observed by axial-position probes, 10 micrometers (0.5 mil).

Note: If all reasonable efforts fail to achieve the limits noted in 4.5.1.4 the vendor and the purchaser shall mutually agree on alternate acceptance criteria.

## 4.5.2 Rotors

**4.5.2.1** Gas generator rotors and rotors of single shaft turbines shall be mechanically designed to safely withstand momentary speeds up to 110 percent of the turbine trip speed settings throughout the specified firing temperature range. The vendor shall state in the proposal any inspections that would be required after such momentary overspeed conditions have occurred; these inspections would have to be made before restart for continuous full-load service.

**4.5.2.2** In the event of an instantaneous loss of 100 percent of site rated load and the driven inertia, turbine rotors must be capable of safe operation without the blades, disks, or shafts fracturing or separating as a result of the ensuing overspeed. The vendor shall state in the proposal any inspections or maintenance required when overspeed excursions exceed the normal overspeed trip limits.

**4.5.2.3** Each rotor shall be clearly marked with a unique identification number. This number shall be in an accessible area that is not prone to maintenance damage.

## 4.5.3 Disk and Blading

**4.5.3.1** The tips of rotating blades and the labyrinths of shrouded rotating blades shall be designed to allow the unit to start up at any time in accordance with the vendor's requirements. When the design permits rubbing during normal start up, the component shall be designed to be rub tolerant and the vendor shall state in his proposal if rubbing is expected.

**4.5.3.2** The blade natural frequencies shall not coincide with any source of excitation from 10 percent below minimum governed speed to 10 percent above maximum continuous speed. If this is not feasible, blade stress levels developed at any specified driven equipment operation shall be low enough to allow unrestricted operation for the minimum service life defined in 4.1.1. Blades shall be designed to withstand operation at resonant frequencies during normal warm-up. The vendor shall state in the proposal the speeds below the operation range corresponding to such blade resonances.

Note: Excitation sources include fundamental and first harmonic passing frequencies of rotating and stationary blades upstream and downstream of each blade row, gas passage splitters, irregularities in vane and nozzle pitch at horizontal casing flanges, the first ten rotor speed harmonics, meshing frequencies in gear units, and periodic impulses caused by the combustor arrangement.

- **4.5.3.3** The blading must have at least 8,000 trouble-free operating hours on similar operating conditions. When specified, the vendor shall present Campbell and Goodman diagrams for the blading backed by demonstrated experience in the application of identical blades operating with the same source or frequency of excitation that is present in the unit. The vendor shall indicate on the Goodman diagrams the standard acceptance margins.

**4.5.3.4** All Campbell diagrams shall show the blade frequencies that have been corrected to reflect actual operating conditions. Where applicable, the diagrams for shrouded blades shall show frequencies above and below the blade lock-up speed and shall specify the speed at which blade lock-up occurs.

## 4.6 SEALS

**4.6.1** Renewable sealing components (such as labyrinths, honeycombs, or abradable surfaces) shall be provided at all internal close-clearance points between the rotating and stationary parts to minimize the leakage of air, gas combustion products, and oil from the casing or housing. The seals shall be designed so that wear occurs predominantly on the replaceable components.

**4.6.2** Renewable seals shall be provided at all external points where shafts pass through the casings.

## 4.7 DYNAMICS

### 4.7.1 Critical Speeds

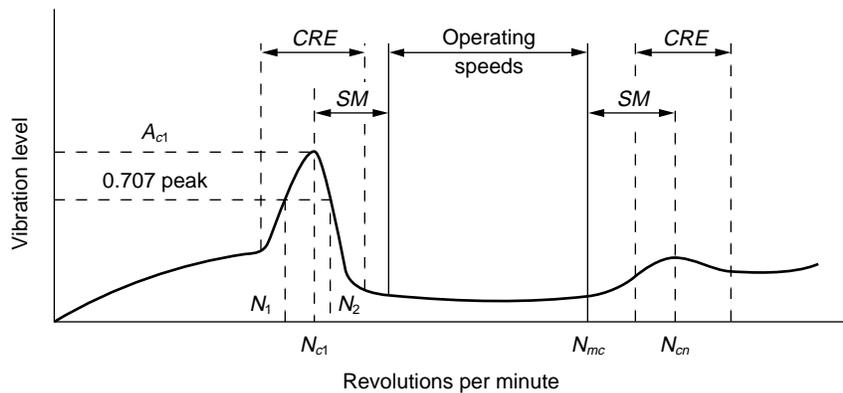
**4.7.1.1** Items a through c below present specific definitions for use in the dynamics section, including Appendix D:

- a. 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.
- b. 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 the mode shape taken by the rotor.

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

c. 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.

- **4.7.1.2** This standard recognizes that gas turbine engines are designed and developed as standard products and applied to well-developed turbine packaged drive systems. The engine design shall meet the life expectations of 4.1.1. This standard requires that the engine manufacturer conduct the following rotor dynamic analysis and testing as required during the engine development or rotor system modification and submit the data or reports as requested by the purchaser. The following, 4.7.1.2.1 through 4.7.1.2.3, are a guide to the analytical development and testing report submittals.



- $N_{c1}$  = rotor 1st 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

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

- Unbalance in the rotor system.
- Oil-film instabilities (whirl).
- Internal rubs.
- Blade, vane, nozzle, and diffuser passing frequencies.
- Gear-tooth meshing and side bands.
- Coupling misalignment.
- Loose rotor-system components.
- Hysteretic and friction whirl.
- Boundary-layer flow separation.
- Acoustic and aerodynamic cross-coupling forces.
- Asynchronous whirl.
- Ball/race frequencies of antifriction bearings.

**4.7.1.2.2** Resonances of structural support systems may adversely affect the rotor vibration amplitude. Therefore, resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the specified separation margins (see D.1.5, Items a through d) unless the resonances are critically damped.

**4.7.1.2.3** The vendor who is specified to have unit responsibility shall determine that the drive-train (turbine, starting driver, and/or helper and the like) critical speed (rotor lateral, system torsional, blading modes, and the like) will not interact with any critical speed of the machinery being supplied and that the entire train is suitable for the specified operating speed range, including any starting-speed detent (hold-point) requirements of the train. A list of all speed ranges to be avoided from zero to trip shall be submitted to the purchaser for review and included in the instruction manual for guidance (see 7.3.6).

## 4.7.2 Lateral Analysis

**4.7.2.1** The vendor's standard critical speed values that have previously been analytically derived and test proven for prior manufactured gas turbines of the same frame size and rotor/bearing configuration are acceptable and shall be submitted to the purchaser. For prototype turbine designs and/or new or modified rotor/bearing configurations, the vendor shall perform a lateral damped unbalance response analysis in accordance with Appendix D. (See 4.7.1.2.)

### 4.7.3 Torsional Analysis

**4.7.3.1** Excitations of torsional resonances may come from many sources, which should be considered in the analysis. These sources may include but are not limited to the following:

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

**4.7.3.2** The undamped torsional natural frequencies of the complete train shall be at least 10 percent above or 10 percent below any mutually agreed excitation frequency within the specified operating speed range (from minimum to maximum continuous speed). With purchaser's prior approval, identical trains which can demonstrate experience of 8,000 or more problem free operating hours are exempted from this requirement. Whenever undamped torsional natural frequencies fall within 10 percent of the specified operating speed range, the vendor shall make available suitable analytical data for the purchaser to verify "identical trains."

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

**4.7.3.4** When torsional resonances are calculated to fall within the margin specified in 4.7.4.2 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

- **4.7.3.5** For electric generator drives and units including gears, or when specified for other units, the vendor that has unit responsibility (see 4.7.1.2.3) shall perform a torsional vibration analysis of the complete coupled train and shall be responsible for directing the modifications necessary to meet the requirements of 4.7.4.1 through 4.7.4.4. The analysis shall include the effects of the starting device as part of the train and, if appropriate, the starting device uncoupled. Report requirements are specified in 7.2 and Appendix B.

### 4.7.4 Vibration and Balancing

**4.7.4.1** Major parts of the rotating element, such as the shaft, disks, drums, and components with blades installed, shall be dynamically balanced. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key. The initial balance correction to the bare shaft shall be recorded. A shaft with keyways 180 degrees apart but not in the same transverse plane shall also be filled as described above.

**4.7.4.2** The balancing method described in 4.7.4.2.1 shall be used on gas turbines with rotors that may be removed as an assembled unit. For rotors that cannot be removed as an assembled unit, the method in 4.7.4.2.2 shall be used.

**4.7.4.2.1** The rotating element shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of no more than two major components. Balancing correction shall only be applied to the elements added. Minor correction of other components may be required during the final trim balancing of the completely assembled element. In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 4.7.4.1) shall continue to be used until they are replaced with the final key and mating element. On rotors with single keyways, the keyway shall be filled with a fully crowned half-key. The weight of all half-keys used during 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:

In SI units,

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

In US Customary units,

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

Where:

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

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

$N$  = maximum continuous speed, in revolutions per minute.

When spare rotors are supplied, they shall be dynamically balanced to the same tolerances as the main rotor. With approval of the purchaser, component balance with assembly trim balance may be substituted for the method previously outlined, using the tolerances specified if this is the vendor's standard practice.

Note 1: Wheel and spacer assembly may be considered a major component.

Note 2: For overhung rotors the outboard bearing is normally lightly loaded. The vendor should advise, based on operating experience, the appropriate balance acceptance criteria.

**4.7.4.2.2** The balancing method for the rotor that is progressively assembled as a part of the gas turbine unit assembly (the rotor cannot be removed as an assembly) is as follows:

- a. All rotating parts shall be component balanced.
- b. The rotor shall be assembled for a balance check to the limits specified in 4.7.4.2.1. No correction to the assembled rotor is permitted. If correction is required, the entire rotating element shall be disassembled, and the dynamic balancing of the individual components shall be repeated to achieve the allowable residual unbalance limits.

**4.7.4.3** After the final assembly and balancing of any rotating element have been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance work sheet (see Appendix C).

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

**4.7.4.5** Where vibration monitoring systems are standard on packaged gas turbines, the vendor shall provide the purchaser with the criteria used to define the vendor's acceptable vibration limits. These criteria shall include, but not be limited to, the following:

- a. Locations and the types of sensors.
- b. Filtration and signal conditioning.
- c. Operational conditions.
- d. Acceptance limits.
- e. Experience from previous similar units.

During the factory test of the assembled gas turbine, at any steady state speed within the specified operating range, the amplitude of vibration (measured at the vendor's standard sensor locations) shall not exceed the vendor's standard acceptance limit filtered or unfiltered. The vendor shall make available, prior to or during the test, summary data from previously tested units.

**4.7.4.6** When proximity probes are being used, electrical and mechanical runout shall be determined and recorded by rolling the rotor or shaft, as applicable, in V blocks at the journal centerline while measuring runout with a noncontacting vibration probe and a dial indicator at the probe location and at one probe tip diameter on either side. Alternate procedures may be required for overhung rotors. The vendor shall submit these procedures to the purchaser.

**4.7.4.7** Accurate records of electrical and mechanical runout, for the full 360 degrees at each location measured in 4.7.4.6, shall be included in the mechanical test report.

**4.7.4.8** When proximity probes are used and if the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 percent of the test level or 6.4 micrometers (0.25 mil), whichever is greater, may be subtracted from the vibration signal measured during the factory test.

## 4.8 BEARINGS AND BEARING HOUSING

### 4.8.1 General

**4.8.1.1** The vendor shall provide their standard bearing design and include bearing description in the proposal. Hydrodynamic radial and thrust bearings are preferred. It is recognized, however, that certain classes of gas turbines are designed to use rolling element bearings.

**4.8.1.2** Bearings shall have sufficient ultimate load capability to withstand forces resulting from failure of any turbine component that requires immediate shutdown (such as loss of a blade or bucket) in order to prevent excessive secondary damage to the turbine.

### 4.8.2 Rolling Element Bearings

**4.8.2.1** Bearing detail and installation design for each bearing location shall be based on a load-life analysis, which as a minimum, shall provide for consideration of the following:

- a. Rotor weight reactions.
- b. Vibratory loading.
- c. Preloading.
- d. Misalignment.
- e. Gear loads.
- f. Combined thrust and radial loads.
- g. Off-design point loads.
- h. Blade-out loads (loss of a blade).
- i. Surge loading.

**4.8.2.2** Bearing load rating and calculation methods shall be in accordance with AFBMA Standard 9 for ball bearings and AFBMA Standard 11 for roller bearings.

**4.8.2.3** Bearing installation and mounting practices shall conform to the applicable AFBMA standards.

**4.8.2.4** Bearing tolerances shall not exceed the applicable standards for the class specified for the application and as defined in Section 3 of both AFBMA Standard 7 and AFBMA Standard 11.

**4.8.2.5** Bearings shall be selected to meet an L10 rated life of 50,000 hours continuous operation at ISO continuous rating conditions and 32,000 hours at maximum axial and radial loads and rated speed. (The rating life is the number of hours

at rated bearing load and speed that 90 percent of a group of identical bearings will complete or exceed before the first evidence of failure).

### 4.8.3 Hydrodynamic Radial Bearings

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

**4.8.3.2** 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 4.7.4.5) while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency.

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

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

### 4.8.4 Thrust Bearings

#### 4.8.4.1 General

**4.8.4.1.1** Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and setting of the bearings clearance or preload.

**4.8.4.1.2** 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:

- Fouling and variation in seal clearances up to twice the design internal clearances.
- Step thrust from all diameter changes.
- Stage reaction and stage differential pressure.
- Variations in inlet, bleed, injection, and exhaust conditions.
- External loads from the driven equipment, as described in 4.8.4.1.3 through 4.8.4.1.5.

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

In SI units:

$$F = \frac{(0.25)(9,550)P_r}{N_r D} \quad (2)$$

In US Customary units, this translates to:

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

Where:

$F$  = external force, in kilonewtons (pounds).

$P_r$  = rated power, in kilowatts (horsepower).

$N_r$  = rated speed, in revolutions per minute.

$D$  = shaft diameter at the coupling in millimeters (inches).

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

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

**4.8.4.1.5** 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 provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

#### 4.8.4.2 Hydrodynamic Thrust Bearings

**4.8.4.2.1** Hydrodynamic thrust bearings shall be of the steel-backed babbitted multi-segment type, designed for the maximum thrust on the active side. The bearing shall be arranged for continuous pressurized lubrication and shall be of the tilting-pad type, incorporating a self-leveling feature that assures that each pad carries an equal share of the thrust load with minor variation in pad thickness. Each pad shall be designed and manufactured with dimensional precision (thickness variation) that will allow interchange or replacement of individual pads. It is preferred that both the active and inactive sides of the thrust bearing use the same size and type of tilt-pad bearing; however, it is recognized that other bearing types may be used on the inactive side.

**4.8.4.2.2** Integral thrust collars are preferred for hydrodynamic thrust bearings. When integral collars are furnished, they shall be provided with at least 3.0 millimeters ( $1/8$  inch), of additional stock to enable refinishing if the collar is damaged. When replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

**4.8.4.2.3** Both faces of the assembled rotor thrust collars for hydrodynamic thrust bearings shall have a surface finish of not more than 0.5 micrometers (16 microinches) Ra, and the axial total indicated run out of either face shall not exceed 12 micrometers (0.0005 inch).

**4.8.4.2.4** Hydrodynamic thrust bearings shall be selected at no more than 50 percent of the bearing manufacturer's ultimate load rating at site rated power. 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, filtration levels, and supply temperature of the oil.
- f. The design configuration of the bearing.
- g. The babbitt alloy.
- h. The turbulence of the oil film.

The sizing of hydrodynamic thrust bearings shall be reviewed and approved by the purchaser.

Note: Thrust bearing size shall be checked to ensure that the thrust bearing rating is adequate for GT maximum potential horsepower. This condition will most likely be at the minimum site ambient temperature.

#### 4.8.5 Bearing Housings

**4.8.5.1** Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 33°C (60°F) under the most adverse specified operating conditions. When the vendor's design inlet oil temperature exceeds 50°C (122°F), special consideration shall be given to bearing design, oil flow, and viscosity, and allowable temperature rise.

**4.8.5.2** 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. Cooling, eductors, or both may be provided.

**4.8.5.3** Where space allows, 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 one-event-per-revolution probe in each machine. The probe installation shall be as specified in API Standard 670.

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

**4.8.5.5** Unless otherwise specified, hydrodynamic thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API Standard 670.

#### 4.9 LUBRICATION

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

- **4.9.2** When specified by the purchaser or required by the vendor, a synthetic lubrication oil may be used. In the proposal, the vendor shall provide a complete description of the proposed system.

**4.9.3** The vendor shall advise the purchaser of all lubricants and lubricant specification requirements for the package.

**4.9.4** All materials used in the construction of the lubrication system shall be compatible with the lubricants specified by either the purchaser or the vendor.

- **4.9.5** The purchaser will specify whether the driven equipment lube-oil systems and seal oil systems, if applicable, are to be separate or combined. If separate systems are specified, the means of preventing interchange of oil between the two systems shall be described in the vendor's proposal.

**4.9.6** Unless otherwise specified, a pressurized oil system shall be furnished to supply oil at a suitable flow, temperature, and pressure or pressures, as applicable, to the following:

- a. The bearings of the driver and the driven equipment (including any gear).
- b. The continuously lubricated couplings.
- c. The governing and control-oil system.
- d. The seal-oil system, if combined with the lube-oil system.

Note: The lubrication system is normally an integral part of the gas turbine package, built into the turbine package support frame.

**4.9.7** In general, oil systems shall comply with API Standard 614. All modifications from API Standard 614 require purchaser approval.

Note: In keeping with the packaging concept, strict compliance with API Standard 614 may not be practical. Differences from this standard may include (but are not limited) to the following:

- a. Reservoir retention time.
  - b. Synthetic oil supply temperature.
  - c. Reservoir material.
  - d. Drain system slopes.
  - e. Twin oil coolers.
  - f. Instrumentation items.
- **4.9.8** Where oil is supplied from a common system to two or more machines (such as compressor, a gear, 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 supplying equipment served by the common oil system.

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

## 4.10 MATERIALS

### 4.10.1 General

- **4.10.1.1** Materials of construction shall be manufacturer's standard for the specified operating conditions, except as required or prohibited by data sheets or this standard (see 5.5.1 for requirements for auxiliary piping materials). The purchaser will specify any corrosive agents present in the motive and process fluids, and/or in the environment. The materials of construction of all major components and all other components which come in contact with the purchaser's specified corrosive agents shall be clearly stated in the vendor's proposal. Any changes to the vendor's standard parts lives service life which are due to the purchaser's specified corrosive agents shall also be clearly stated in the vendor's proposal.

**4.10.1.2** Materials shall be identified in the proposal with internationally recognized material designation numbers and grade where applicable. When no such designation is available, the vendor's material specification, given material properties, chemical components, and test requirements, shall be included in the proposal. Any component or coating material which does not have at least 16,000 hours total experience (of which 8,000 hours shall be continuous in one machine) shall be identified in the proposal.

**4.10.1.3** The vendor shall specify the optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The purchaser may consider specifying additional tests and inspections, especially for materials used in critical components.

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

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

**4.10.1.6** When parts made of austenitic stainless steel are fabricated, hard surfaced, overlaid or repaired by welding, and exposed to a motive or process fluid or environmental condition which promotes intergranular corrosion, low carbon or stabilized grades of stainless steel shall be used.

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

**4.10.1.7** Where mating parts such as studs and nuts of AISI Standard Type 300 series stainless steel or materials with similar galling tendencies are used, they shall be lubri-

cated with an antiseizure compound suitable for the operating temperature and compatible with the specified gas.

**4.10.1.8** When dissimilar materials with different electrical potentials are placed in contact in the presence of an electrolyte solution, galvanic couples that can result in serious corrosion of the less noble materials may be created. If such conditions exist, the purchaser and the vendor should select materials in accordance with *The NACE Corrosion Engineer's Reference Book*.

**4.10.1.9** Materials, casting factors, and the quality of any welding shall be as a minimum equal to those required by Section VIII, Division 1, of the ASME Code. The vendor's data report forms, as specified in the code, are not required. The vendor shall specify in the proposal if an alternate internationally recognized pressure vessel I code is used.

**4.10.1.10** The use of ASTM A515 steel is prohibited. 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.

**4.10.1.11** The minimum quality bolting material for pressure joints shall be carbon steel (ASTM A 307, grade B) for cast iron casings and high temperature alloy steel (ASTM A 193, grade B7) for steel casings. Nuts shall conform to ASTM A 194M grade 2H (or ASTM A 307, grade B, case hardened, where space is limited). For temperatures below  $-30^{\circ}\text{C}$  ( $-20^{\circ}\text{F}$ ), low temperature bolting material in accordance with ASTM A 320 shall be used.

Note: To avoid brittle failure during operation, maintenance, transportation, erection, and testing, good design practices shall be followed in the selection of fabrication methods, welding procedures, and materials for vendor furnished carbon steel piping and appurtenances that may be subject to temperatures below the ductile-brittle transition point. The published design-allowable stresses for many materials in the ASME Code and ANSI standards are based on minimal tensile properties. They do not differentiate between rimmed, semikilled, fully killed, hot rolled, and normalized material, nor do they take into account whether materials were produced under fine or course grain practices. The vendor shall exercise caution in the selection of materials intended for service between  $-30$  to  $40^{\circ}\text{C}$  ( $-20$  to  $100^{\circ}\text{F}$ ).

### 4.10.2 Castings

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

**4.10.2.2** 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 compatible with the casting.

**4.10.2.3** Ferrous castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 4.10.2.3.1 and 4.10.2.3.2.

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

**4.10.2.3.2** 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.

**4.10.2.4** Fully enclosed core voids, including voids caused by plugging, are prohibited.

**4.10.2.5** Nodular iron castings shall be produced in accordance with ASTM A 395. The production of the castings shall be to the conditions specified in 4.10.2.5.1 through 4.10.2.5.5.

**4.10.2.5.1** A minimum of one set (three samples) of Charpy V-notch impact specimens at one third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y block. These specimens shall have a minimum impact value of 14.0 joules (10 foot pounds) at room temperature.

**4.10.2.5.2** The keel or Y block cast at the end of the pour shall be at least as thick as the thickest section of the main casting.

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

**4.10.2.5.4** An as-cast sample from each ladle shall be chemically analyzed.

**4.10.2.5.5** Brinell hardness readings shall be made on the actual castings at feasible locations on section changes and flanges. Sufficient surface materials shall be removed before hardness readings are made to eliminate any skin effects. Readings shall also be made at the extremities of the casting at location that represent the sections poured first and last. These shall be made in addition to Brinell readings in the keel or Y blocks.

### 4.10.3 Forgings

Compressor and turbine disk forgings shall have transition temperatures (at the bore sections) that are below minimum specified ambient temperatures.

### 4.10.4 Welding

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

**4.10.4.2** The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedure (see 4.10.1.10).

**4.10.4.3** Unless otherwise specified, all welding other than that covered by Section VIII, Division 1, of the ASME Code and ASME B31.3, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed in accordance with AWS D1.1, as a minimum. The vendor shall specify in the proposal if an alternate code is used.

**4.10.4.4** Repair welds shall be nondestructively tested by the same method used to detect the original flaw. As a minimum, this shall be in accordance with 6.2.2.4 for magnetic material, and by the liquid penetrant method in accordance with 6.2.2.5 for nonmagnetic material.

**4.10.4.5** Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 4.10.4.5.1 through 4.10.4.5.4.

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

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

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

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

**4.10.4.6** Connections welded to pressure casings shall be installed as specified in 4.10.4.6.1 through 4.10.4.6.5.

- **4.10.4.6.1** In addition to the requirements of 4.10.4.1, the purchaser may specify that 100-percent radiography, magnetic particle inspection, or liquid penetrant inspection of welds is required.

**4.10.4.6.2** Auxiliary piping welded to chromium-molybdenum alloy steel or 12-percent chrome steel components shall be of the same material, except that chromium-molybdenum alloy steel pipe may be substituted for 12-percent chrome steel pipe.

**4.10.4.6.3** Piping welds shall be made before the component is heat treated.

- **4.10.4.6.4** When specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawing shall show weld design, size, materials, and pre- and post-weld heat treatments.

**4.10.4.6.5** All welds shall be heat treated in accordance with Section VIII, Division 1, US-40, of the ASME Code. The vendor shall specify in the proposal if an alternate code is used.

#### 4.10.5 Impact Test Requirements

**4.10.5.1** To avoid brittle fracture during operation, maintenance, transportation, erection, and testing, good design practice shall be followed in the selection of fabrication methods, welding procedures, and materials for vendor furnished steel pressure retaining parts that may be subject to temperature below the ductile-brittle transition point.

Note: The published design-allowable stresses for many materials in the ASME Code and ANSI standards are based on minimal tensile properties. The ASME Code and ANSI standards do not differentiate between rimmed, semikilled, fully killed, hot rolled, and normalized material. Nor do they take into account whether materials were produced under fine or course grain practices. The vendor shall exercise caution in the selection of materials intended for service between -30 to 40°C (-20 to 100°F).

**4.10.5.2** All pressure-containing components including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of Section VIII, Division 1, Section USC-65 through 68, of the ASME Code. High-alloy steels shall be tested in accordance with Section VIII, Division 1, Section UHA-51, of the ASME Code.

Impact testing is not required if the requirements of Section VIII, Division 1, Section UG-20F, of the ASME Code are met.

Nominal thickness for castings as defined in Section VIII, Division 1, Paragraph UCS-66(2), of the ASME Code shall exclude structural support sections such as feet or lifting lugs.

The results of the impact testing shall meet the minimum impact energy requirements of Section VIII, Division 1, Section UG-84, of the ASME Code. The vendor shall specify in the proposal if an alternate code is used.

- **4.10.5.3** The purchaser will specify the minimum design metal temperature used to establish impact test requirements.

#### 4.11 NAMEPLATES AND ROTATIONAL ARROWS

**4.11.1** A nameplate shall be securely attached to an easily accessible point on the equipment and on any other major piece of auxiliary equipment.

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

**4.11.3** The following data, as a minimum, shall be clearly stamped on the nameplates of the gas turbine units. Units used on the nameplates shall correspond to those used on the datasheets:

- Vendor's name.
- Serial number.
- Model.
- Site rated power and speed.
- Site rated temperature.
- Site rated inlet pressure.
- Site rated exhaust pressure.
- Site rated firing temperature.
- Lateral critical speeds (see note).
- Maximum continuous speed.
- Overspeed trips.
- Fuel types.

Note: Any lateral critical speeds determined from running tests shall be stamped on the nameplate followed by the word "TEST." Critical speeds predicted by calculation up to and including the critical speed above trip speed and not identifiable by test shall be stamped on the nameplate followed by the abbreviation "CALC."

#### 4.12 QUALITY

Refer to API Recommended Practice 683 for guidelines on improving the quality of equipment.

### 5 Accessories

#### 5.1 STARTING AND HELPER DRIVER

##### 5.1.1 General

- **5.1.1.1** The vendor shall furnish a starting or helper driver as specified. The types of drivers available include electric motors, steam turbines, gas expansion turbines, internal combustion engines, hydraulic motors, and small gas turbines.

Note 1: Starting drivers are used to accelerate gas turbines (and driven equipment for single shaft machines) to self-sustaining speed and are normally idle during operation.

Note 2: Helper drivers are used to accelerate gas turbines and driven equipment to self-sustaining speed and usually remain coupled during operation to provide supplementary shaft power to the gas turbine trains.

**5.1.1.2** Starting steam turbines shall be general-purpose turbines in accordance with API Standard 611.

**5.1.1.3** Unless otherwise specified, helper steam turbines shall be special-purpose turbines in accordance with API Standard 612.

**5.1.1.4** Motor drives shall conform to API Standard 541. Motors that are below the power scope of API Standard 541 shall be in accordance with IEEE 841.

- **5.1.1.5** The motor's starting-torque requirements shall be met at a specified reduced voltage.

Note: For most applications, the starting voltage is typically 80 percent of the normal voltage.

- **5.1.1.6** The purchaser will designate the applicable specifications and standards for other types of starting and helper drivers.

**5.1.1.7** The turbine vendor shall supply any clutches, speed-changing gears, torque converters, or other power transmission equipment, including controls, required or specified for the starting and helper drivers.

**5.1.1.8** For drivers that weigh more than 250 kilograms (500 pounds) the equipment feet shall be provided with jackscrews.

**5.1.1.9** Starting drivers and their associated power transmission equipment shall be sized for acceleration of the gas turbine unit and for extended operation at purge, compressor cleaning cycles, and when required, warm-up speeds. Any starting driver not suitable for operation at speeds corresponding to turbine trip speed shall disengage automatically and shut down at its maximum allowable speed or trip speed, as applicable. Failure of the starting driver to disengage shall automatically abort the starting sequence.

**5.1.1.10** A gas-expansion starter or helper turbine using flammable gas for motive power shall be designed for zero leakage shaft seals.

## 5.1.2 Ratings

**5.1.2.1** Starting driver ratings shall be determined by the gas turbine vendor. As a minimum, the drivers shall be rated to supply 110 percent of the starting and acceleration torque required by the gas turbines (and the driven equipment trains for single shaft machines) throughout the specified ambient temperature range. The gas turbine vendor shall prepare a speed-torque curve for the turbines and driven equipment, with the starting driver torque superimposed.

- **5.1.2.2** Helper driver ratings and arrangements shall be mutually agreed to by the purchaser and the vendor.

## 5.1.3 Turning Equipment

- **5.1.3.1** A turning gear and/or ratchet device shall be furnished, if specified by the purchaser or if required to avoid rotor deformation after a tripout. Details of turning gear operation, such as manual or automatic engagement/disengagement, shall be mutually agreed upon by the purchaser and the vendor.

**5.1.3.2** Turning gears shall not engage without adequate system lube-oil pressure at all bearings.

**5.1.3.3** Turning gears shall not depend on the starting driver clutches for operation.

**5.1.3.4** Provisions shall be made to allow for the manual barring of the gas turbine during failure or upon loss of power to the turning gear or ratchet device.

## 5.2 GEARS, COUPLINGS, AND GUARDS

### 5.2.1 Gears

- **5.2.1.1** The gas turbine vendor shall furnish any gear required for starting and helper drivers, shaft-driver auxiliary equipment, and when specified, any load gear.

**5.2.1.2** Load gears and helper driver gears shall be separate coupled units and shall comply with API Standard 613.

**5.2.1.3** Load gears shall have minimum ratings equal to the potential maximum power of the gas turbine, plus the rated power of any helper drivers transmitting power through the gears. If this results in excessive horsepower ratings, actual gear ratings shall be agreed upon by the purchaser and the vendor.

**5.2.1.4** Auxiliary gears shall be the vendor's standard for the service but shall be rated for at least 110 percent of the power developed by any starting and helper drivers coupled to them and of the power required by any driven auxiliaries.

### 5.2.2 Couplings and Guards

**5.2.2.1** The gas turbine vendor shall furnish couplings and guards (including adapter plates) between the turbine and starting/helper driver, auxiliary gears, load gear, or the first piece of load equipment.

**5.2.2.2** Main load couplings shall be sized for maximum continuous torque, which is based on the potential maximum power of the gas turbine plus the maximum applicable helper turbine power output.

**5.2.2.3** Coupling, coupling-to-shaft junctures, and guards shall conform to API Standard 671. Couplings shall be sized to API 671 except as modified by 5.2.2.1 and 5.2.2.2. The make, type, and mounting arrangement of couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment.

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

## 5.3 MOUNTING PLATES

### 5.3.1 General

- **5.3.1.1** The gas turbine unit, as well as its starting equipment, lubrication system, and other auxiliaries, shall be furnished with soleplates or baseplates as specified.

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

**5.3.1.2.1** All machinery mounting surfaces shall meet the following criteria after fabrication is completed:

- They shall extend at least 25 millimeters (1 inch) beyond the outer two sides of the equipment feet.
- The surface of each mounting pad shall be machined with a flatness of 13 micrometers per 33 linear centimeters (0.0005 inches per linear foot) of pad mounting surface.
- To prevent a soft foot, all surfaces of the same plane upon which a piece of equipment mounts shall be in the same plane within 50 micrometers (0.002 inch).
- Different mounting planes shall be parallel to each other within 50 micrometers (0.002 inches).
- The maximum surface finish shall be 3 micrometers (125 microinches) Ra.

**5.3.1.2.2** When the equipment supported weighs more than 250 kilograms (500 pounds), the mounting plates shall be furnished with jackscrews. Vertical jackscrews in the equipment feet shall be arranged to prevent marring of shimming surfaces. The lugs holding these jackscrews shall be attached to the mounting plates so that the lugs do not interfere with the installation or removal of the equipment jackscrews or shims. If the equipment is too heavy to use jackscrews, other means shall be provided.

**5.3.1.2.3** Machinery supports shall be designed to limit a change of alignment caused by the worst combination of pressure, torque, and allowable piping stress to 50 micrometers (0.002 inch) at the coupling flange. (See 5.5.6.6 for allowable piping forces.)

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

**5.3.1.2.5** Unless otherwise specified, epoxy grout shall be used. The vendor shall commercially sandblast, in accordance with SSPC SP 6, all the grout contact surfaces of the mounting plates and shall coat these surfaces with inorganic zinc silicate in preparation for epoxy grouting. The vendor shall submit to the purchaser instructions for field preparation of the epoxy primer.

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

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

**5.3.1.2.8** Mounting plates shall be designed to extend at least 25 millimeters (1 inch) beyond the outer three sides of equipment feet.

**5.3.1.2.9** The vendor shall furnish stainless steel (AISI Standard Type 300) shim packs 3 to 13 millimeters ( $1/8$  to  $1/2$  inch) thick between the equipment feet and the mounting plates. All shim packs shall straddle the hold-down bolts and vertical jackscrews and be at least 6 millimeters ( $1/4$  inch) larger on all sides than the footprint of the equipment.

**5.3.1.2.10** Anchor bolts will be furnished by the purchaser.

**5.3.1.2.11** Fasteners for attaching the components to the mounting plates and jackscrews for leveling the pedestal mounting plates shall be supplied by the vendor.

### 5.3.2 Baseplate

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

Note: A baseplate with a nominal length of more than 12 meters (40 feet) or a nominal width of more than 4 meters (12 feet) or overweight may have to be fabricated in multiple sections because of shipping restrictions.

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

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

- **5.3.2.4** When specified, the baseplate shall be suitable for column mounting (that is, of sufficient rigidity to be supported at specific points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

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

**5.3.2.6** When the baseplate is installed on a concrete foundation, the bottom between structural members shall be open. It shall be provided with at least one grout hole having a clear area of at least 0.01 square meter (20 square inches) and no dimension less than 75 millimeters (3 inches) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed. The holes shall have 15-millimeter ( $1/2$ -inch) raised-lip edges and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least 15 millimeters ( $1/2$  inch) in size shall be provided at the highest point in each bulkhead section of the baseplate.

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

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

**5.3.2.9** The baseplate mounting pads shall be machined after the baseplate has been fabricated.

### 5.3.3 Soleplates and Subsoleplates

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

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

**5.3.3.1.2** Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall the plates be less than 40 millimeters ( $1\frac{1}{2}$  inches) thick.

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

## 5.4 CONTROLS AND INSTRUMENTATION

### 5.4.1 General

**5.4.1.1** Instrumentation and installation shall conform to any detailed specifications in the purchaser's inquiry or order or both. When no detailed specifications are furnished, instru-

mentation and installation shall conform to the requirements of API Standard 614.

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

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

**5.4.1.4** The turbine control system shall provide for start up of the gas turbine unit, provide for stable operation, warn of abnormal conditions, monitor the operation, and shut down the unit. A governor shall be provided which will meet the Class-D steady-state speed regulation and speed variation sections of ANSI B133.4.

**5.4.1.5** The control system may be mechanical, pneumatic, hydraulic, electric, electronic, microprocessor based, or any combination thereof. The vendor's proposal shall state the degree of redundancy, if any, of his standard control.

- **5.4.1.6** When specified, the control system shall be designed to maintain turbine operation and protection for a purchaser-specified time period in the event of an interruption of AC power.

### 5.4.2 Starting Control Systems

- **5.4.2.1** The starting control system may be manual, semi-automatic, or fully automatic, as specified. The starting cycle of the turbine shall be automatic unless otherwise specified. The commissioning of accessories and auxiliaries and the starting sequence shall be as follows:

a. Manual start, if specified, shall require the operator to commission the accessory and auxiliary equipment; initiate, hold, and advance (crank, purge, and fire) the starting sequence; and accelerate the turbine to the minimum governor setting.

b. Semiautomatic start, if specified, shall require manual commissioning of the accessories and auxiliaries and shall permit the operator to commit the turbine to the complete starting sequence by a single action.

c. Automatic start shall require only a single action by the operator to commission auxiliary equipment and initiate the complete sequence.

**5.4.2.2** Control systems shall provide a purge period of sufficient duration to permit the gas turbine to displace to volume of the entire exhaust system (including the stack) three to five times before firing the unit.

**5.4.2.3** The control system shall provide sufficient time for the turbine internals to warm up to reduce thermal strain effects and, if necessary, to heat rotating parts (turbine shaft and disks) to a temperature above any transition temperature.

**5.4.2.4** The control system shall provide controlled acceleration to the minimum governor speed setting in order to reduce thermal strain effects, excessive mechanical stresses, or operation at critical speeds.

**5.4.2.5** When the starting fuel is different from the normal fuel, starting shall be accomplished using the same fuel control system.

### 5.4.3 Load Control

**5.4.3.1** The gas turbine shall be provided with an actuator that will receive the purchaser's control signal. During normal operation, this external control signal shall control turbine speed or power as required. The governor shall be capable of accessing the full range of the purchaser's control signal. An increase in signal shall increase the turbine speed or power unless otherwise specified. The governor shall include a means to manually override the external control signal and permit operation between the minimum governor speed and the maximum continuous speed. The governor shall provide smooth (bumpless) transfer between manual and automatic external control modes.

**5.4.3.2** For a variable-speed drive, the control signal shall act to adjust the set point of the driver's speed-control system. Unless otherwise specified, the control range shall be at least from 5 percent above to 5 percent below the output shaft operating speed range specified in 4.1.1.

**5.4.3.3** The full range of the specified control signal will correspond to the required operating range of the driven equipment. Unless otherwise specified, the maximum control signal will correspond to the maximum continuous speed.

**5.4.3.4** The governor for mechanical drive applications shall limit speed to 105 percent of rated speed.

**5.4.3.5** Multiple shaft turbines shall also be provided with a speed limiter on the gas generator, set for maximum continuous speed.

**5.4.3.6** Governor systems shall prevent the gas turbine from tripping overspeed when an instantaneous loss of electric, hydraulic, or aerodynamic load occurs.

### 5.4.4 Alarms and Shutdowns

**5.4.4.1** The vendor shall provide an integrated sensing, alarm, shutdown, and display system for conditions that could result in damage to the gas turbine unit or could shorten the life of the unit. Starting equipment shall be interlocked to prevent rotation of the unit until conditions are safe for starting.

**5.4.4.2** A shutdown may be normal or an emergency. Sequences for either shall be automatic:

a. Normal shutdown shall follow an orderly, safe, step-by-step procedure based on the requirements of the specific machinery and applications.

b. Emergency shutdown may be manually activated or may occur as a result of the operation of a protective device. The system shall cause the fuel shutoff valve to cut off the fuel supply and shall limit speed to the values shown in 4.5.2.1. Where practical, means shall be provided to prevent restarting before corrective action has taken place.

Consideration shall be given to the relationship between turbine controls and driven equipment. Unless otherwise specified, automatic means shall be provided for isolating, upon shutdown, the driven equipment from the system that it is supplying in order to prevent motoring or reverse flow. Operating venting systems for the release of stored energy may also be necessary.

**5.4.4.3** The fuel control system shall include shutoff valve, separate from the fuel control valve, that stops all fuel flow to the turbine on any shutdown condition and can not open until all permissive firing conditions are satisfied. The valve shall have a means for local and remote tripping and a local manual mechanical device for tripping.

**5.4.4.4** A vent valve shall be provided on gas fuel systems. The valve shall automatically vent the piping downstream of the shutoff valve when the shutoff valve closes. The vent valve may be an integral part of the shutoff valve, or it may be separate.

**5.4.4.5** The fuel governor device shall call for zero fuel on any shutdown condition.

**5.4.4.6** An overspeed trip protection shall operate at 105 percent of maximum continuous speed. Multiple shaft turbines shall have individual overspeed trip protection for each shaft.

**5.4.4.7** Switches, control devices, and annunciation display units shall be furnished and mounted by the vendor as specified by the purchaser.

Annunciated alarm and shutdown conditions may include those listed in Table 1. When an alarm function in addition to a shutdown function is specified, the alarm shall be set to precede the shutdown so that corrective action may be taken.

**5.4.4.8** The alarm and trip switch requirements are described in 5.4.4.8.1 through 5.4.4.8.8.

**5.4.4.8.1** Each alarm switch and each shutdown switch shall be furnished in a separate housing. Single-pole, double throw switches shall be used.

**5.4.4.8.2** Unless otherwise specified, electric switches that open (de-energize) to alarm and close (energize) to trip shall be used.

Table 1—Typical Alarm and Shutdown Annunciation

Condition	Annunciated	
	Alarm	Shutdown
Radial shaft vibration	X	X <sup>a</sup>
Axial thrust position	X	X <sup>a</sup>
Overspeed		X
Casing vibration	X	
High thrust or radial bearing temperature	X	
Low fuel supply pressure	X	X
Turbine exhaust over-temperature	X	
Failure of exhaust over-temperature shutdown device	X	
High differential pressure in each air inlet filter	X	
Combustor-stage flameout	X	X
Control system failure	X	
Failure of starting clutch to engage or disengage	X	
Low lube-oil pressure	X	X
High or low lube-oil reservoir level	X	
Lube-oil filter differential pressure	X	
Lube-oil spare pump operation	X	
Low control-oil pressure	X <sup>a</sup>	
Other protective devices on turbine auxiliaries	X	
Other process or driven equipment functions	X <sup>a</sup>	X

<sup>a</sup>Optional.

**5.4.4.8.3** Alarm and trip switch settings shall not be adjustable from outside the housing. Pressure elements shall be of 18-8 stainless steel. Alarm and shutdown switches shall be arranged to permit testing of the control circuit, including the actuating element where possible, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in the test bypass mode. Low-pressure alarms shall be equipped with valved bleed or vent connections to allow controlled depressurizing so that the operator can note alarm set pressure on the associated pressure gauge. Similarly, high-pressure alarms shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure. In addition, shutdown systems shall be provided with electrical disconnect switches or other suitable means to permit testing without shutting down the unit. The vendor shall furnish with the proposal complete descriptions of the alarm and shutdown testing facilities to be provided.

**5.4.4.8.4** An alarm bell or horn that will be actuated by the alarm or shutdown relay shall be provided on the control panel.

- **5.4.4.8.5** The vendor shall furnish a first-out annunciator when an annunciator system is specified. The annunciator shall contain approximately 20 percent spare points and,

when specified, shall be suitable for purging. Connections shall be provided for actuation of a remote signal when any function alarms or trips. The sequence of operation shall be as specified in 5.4.4.8.6 through 5.4.4.8.8.

**5.4.4.8.6** Alarm indication shall consist of the flashing of a light and the sounding of a horn or another audible device.

**5.4.4.8.7** The alarm condition shall be acknowledged by operating an alarm-silencing button common to all alarm functions.

**5.4.4.8.8** When the alarm is acknowledged, the horn or other audible device shall be silenced, but the light shall remain steadily lit as long as the alarm condition exists. The annunciator shall be capable of indicating a new alarm (with a flashing light and sounding horn) if another function reaches an alarm condition, even if the previous alarm condition has been acknowledged but still exists.

- **5.4.4.9** Unless otherwise specified, all instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their replacement while the system is in operation. When shutoff valves are specified for shutdown sensing devices, the vendor shall provide a means of locking the valves in the open position.

## 5.4.5 Instrumentation and Control Panels

**5.4.5.1** This specification recognizes that gas turbine prime movers are purchased as part of a complete drive package and most often include the driven equipment. This specification shall be applied to both single and two shaft engines and not limited to generator, compressor, or pump drive systems. The purchaser should be aware that other drive equipment or unusual process requirements may require modifications to the control techniques for their unique service.

**5.4.5.1.1** The turbine package supplier shall include a control console either free standing or installed on the package skid.

- Free standing consoles shall be suitable for installation in a nonhazardous, indoor area.
- Package skid mounted consoles shall be suitable for the same area classification as applied to the skid.
- The control system shall be microprocessor based.
- The console shall allow space for the package supplier to mount instruments provided by the purchaser in/on the console.

The control console, including lights, switches, button, visual screens, etc., shall be described in the suppliers' proposal.

**5.4.5.1.2** It is preferred that the control system be of a design that has been proven by experience of having been installed in at least three (3) similar applications and that the system has a total of 10,000 operating hours of service, and

that the system and configuration being provided represent the supplier's standard equipment.

**5.4.5.1.3** The control system shall be either AC or DC powered. In the case of DC power the supplier shall provide a battery charger and battery pack.

**5.4.5.2** A control console may include a visual display unit (VDU) for monitoring operating variables and/or a keyboard for entering operator commands. The VDU may be driven from a microprocessor based system independent of the gas turbine control system, with communication between the visual display monitor and the turbine controls to be accomplished through a data link.

**5.4.5.3** Wiring to switches and instruments on the unit shall be from a single terminal box mounted at the skid edge. Terminal boxes are to be mounted so they are not disturbed during routine maintenance. Wiring shall be installed in conduit. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification. All control cabinets designed to be outdoors which contain electrical contacts, relays, or instruments shall have provisions for dry air purge to prevent contamination and corrosion. Dry air will be furnished by the purchaser.

## 5.4.6 Electrical Systems

- **5.4.6.1** The characteristics of electrical power supplies for motors, heaters, and instrumentation will be specified by the purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. Unless otherwise specified, the pilot lights shall be installed on the control panels.

**5.4.6.2** Electrical equipment located on the unit or on any separate panel shall be suitable for the hazard classification specified. Electrical starting and supervisory controls may be either AC or DC.

**5.4.6.3** Power and control wiring within the confines of the baseplate shall be resistant to oil, heat, moisture, and abrasion. Stranded connectors shall be used within the confines of the baseplate and in other areas subject to vibration. Measurement and remote-control panel wiring may be solid conductor. A high-temperature, oil-resistant thermoplastic sheath shall be provided for wire insulation protection. Wiring shall be suitable for environment temperatures.

**5.4.6.4** Unless otherwise specified, all leads on terminal strips, switches, and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 percent spare terminal points.

**5.4.6.5** To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on turbine and auxiliary equipment. The clear-

ances required for 600-volt service shall also be provided for lower voltages. To guard against accidental contact, enclosures shall be provided for all energized parts.

- **5.4.6.6** Electrical materials including insulation shall be corrosion resistant and non-hygroscopic insofar as is possible. When specified for tropical location, materials shall be given the treatments specified in 5.4.6.6.1 and 5.4.6.6.2.

**5.4.6.6.1** Parts (such as coils and windings) shall be protected from fungus attack.

**5.4.6.6.2** Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

**5.4.6.7** Control, instrumentation, and power wiring (including temperature element leads) within the limits of the baseplate shall be installed in rigid metallic conduits and boxes, properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit. If temperature element heads will be exposed to temperatures above 60°C (140°F), a 19-millimeter (<sup>3</sup>/<sub>4</sub>-inch) bronze hose with four-wall interlocking construction and joints with packed-on (heatproof) couplings shall be used.

**5.4.6.8** For Division 2 locations, flexible metallic conduits shall have a liquid tight thermosetting or thermoplastic outer jacket. For Division 1 locations, an NFPA-approved connector shall be provided.

**5.4.6.9** AC and DC circuits shall be clearly labeled, connected to separate terminal blocks, and isolated from each other.

## 5.4.7 Instrumentation

### 5.4.7.1 General

Temperature instrumentation shall be provided to monitor the important temperatures within the unit display of the non-critical items and to record the more important items such as exhaust temperatures. The vendor shall include in his proposal a complete listing of all critical temperatures which shall be recorded.

### 5.4.7.2 Tachometers

**5.4.7.2.1** A means for measuring and displaying each shaft speed shall be provided. This means may be a part of the turbine control and monitoring system, or a separate tachometer may be provided.

- **5.4.7.2.2** The type of tachometer will be specified. Unless otherwise specified, the minimum range shall be from 0 to

125 percent of the maximum continuous speed (in revolutions per minute).

### 5.4.7.3 Temperature Gauges

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

**5.4.7.3.2** The sensing elements of temperature gauges shall be immersed in the flowing fluid. This is particularly important for lines that may run partially full.

### 5.4.7.4 Thermowells

Temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with  $\frac{3}{4}$ -inch National Pipe Thread (NPT) AISI Standard Type 300 stainless steel separable solid-bar thermowells.

### ● 5.4.7.5 Thermocouples and Resistance Temperature Detectors

Where practical, the design and location of thermocouples and resistance temperature detectors (RTD) shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box. Conduit runs from thermocouple and resistance temperature detector heads to a pull box or boxes located on the baseplate shall be provided. When specified, monitors shall be supplied, installed, and calibrated in accordance with API Standard 670.

### ● 5.4.7.6 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, 110-millimeter (4 $\frac{1}{2}$ -inch) dials, 152-millimeter (6-inch) dials for the range over 55 bar (800 pounds per square inch), and  $\frac{1}{2}$ -inch National Pipe Thread (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.

### 5.4.7.7 Solenoid Valves

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

### 5.4.7.8 Vibration and Position Detectors

**5.4.7.8.1** Unless otherwise specified, vibration and axial position transducers for use with hydrodynamic bearings shall be supplied, installed, and calibrated in accordance with API Standard 670.

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

**5.4.7.8.3** Unless otherwise specified, vibration transducers for use with rolling element bearings shall be supplied, installed, and calibrated in accordance with API Standard 670. When specialized vibration transducers for use with rolling element bearings not covered by API Standard 670, 3rd edition are to be supplied, the vendor shall provide details and specifications for purchaser review.

**5.4.7.8.4** When specified, monitors for use with rolling element bearings shall be supplied and calibrated in accordance with API Standard 670. When specialized vibration monitors for use with rolling element bearings not covered by API Standard 670, 3rd edition are to be supplied, the vendor shall provide the purchaser with details and specifications for purchaser review.

## 5.5 PIPING AND APPURTENANCES

### 5.5.1 General

**5.5.1.1** Auxiliary systems piping shall include design, joint fabrication, examination, and inspection and shall be in accordance with API 614 piping section and as modified or amplified in the following paragraphs.

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

- a. Fuel gas and oil.
- b. Water injection.
- c. Steam injection.
- d. Starting air system.
- e. Instrument and control air.
- f. Compressor bleed air.
- g. Cooling water.
- h. Liquid wash.
- i. Lubrication oil.
- j. Control oil.

- k. Hydraulic oil.
- l. Drains and vents.

Note: Drains and vents are discussed in 4.4.

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

**5.5.1.4** Pipe plugs shall be in accordance with 4.4.4.

## 5.5.2 Oil Piping

**5.5.2.1** Provisions adjacent to bearing housings shall be made for bypassing the bearings of equipment during oil system flushing operations. Disturbed piping shall be kept at a minimum.

## 5.5.3 Inlet and Exhaust Systems

- **5.5.3.1** An air inlet and exhaust system consisting of an air inlet filter, silencers, ducting, and expansion joints shall be supplied. Pressure-drop test connections at the gas turbine inlet and exhaust flanges shall be included. Other devices not covered by the standard exhaust-over-pressure protective devices and diversion valve and exhaust-heat recovery systems may be required. A duct-mounted anti-icing system and an emission control reduction system may also be needed.

**5.5.3.2** When the gas turbine manufacturer does not furnish system components, the purchaser will submit the component designs to the manufacturer for review and comment.

**5.5.3.3** Unless otherwise specified, the inlet system shall be designed for a minimum practical pressure drop with a maximum total pressure drop of 1 kilopascal (4 inches water) with a clean air filter and at least 110 percent of the air flow at site rated power. The exhaust system shall be designed for the minimum practical pressure loss. Where pressure at the turbine exhaust flange is expected to exceed 3.7 kilopascals (15 inches water), the gas turbine manufacturer shall be consulted. The economics of individual applications could dictate other design factors for each system that may be used with the purchaser's agreement.

Pressure losses of 0.5 kilopascal (2 inches water) at the inlet or 4 inches (1 kilopascal) water at the outlet are approximately equivalent to 1 percent power loss each.

- **5.5.3.4** System components, except for filter media, shall be designed for a useful life of at least 20 years. The purchaser will advise the vendor of the site conditions (rainfall, atmospheric contaminants, corrosive elements, and dust) that could affect the system design and the selection of the materials. Provisions shall be made to permit maintenance of inlet filter media during operation of the turbine.

**5.5.3.5** All inlet system components downstream of the inlet filter elements shall be designed for a minimum collapse differential pressure of 3 kilopascals (12 inches water).

**5.5.3.6** Bolts, rivets, or other fasteners that can become loose and be carried in the air stream shall not be used in the inlet system downstream of the final stage of filtration.

Note: The inlet screen (see 5.5.3.7) shall not be considered a stage of filtration.

**5.5.3.7** A reinforced coarse-mesh 6.4 to 12.7 millimeter ( $\frac{1}{4}$  to  $\frac{1}{2}$  inch) stainless steel screen shall be provided immediately ahead of the gas turbine air inlet. The actual location shall be mutually agreed upon by the vendor and the purchaser, both of whom must consider cleaning systems, access plates, viewing windows, vaned elbows, and aerodynamic disturbance of the bellmouth entrance.

**5.5.3.8** Corrosion protection of the filter, ducting, and silencer is required. Protective material or coating and details of the surface preparation proposed shall be submitted by the vendor with the proposal. As a minimum all nonstainless steel inlet components shall be finish coated at the manufacturer's plant prior to shipment.

- **5.5.3.9** A compressor cleaning system shall be provided. The vendor shall describe the type of compressor cleaning system being provided. The vendor shall address in the proposal features and requirements such as: manual or automatic operation, integral-to-package or separate, solvents, and anti-freeze compounds and utilities.
- **5.5.3.10** Based on ambient conditions provided, the vendor shall advise if an anti-icing system is to be provided. If anti-icing is required, the vendor shall fully describe the system, vendor's scope, effect on engine's performance over the ambient range, and required utilities.

Note: Effects of the inlet cooling system, if provided, on icing conditions must also be addressed.

- **5.5.3.11** The purchaser shall specify, if required, any site limits on exhaust emissions. Available or required processes to be used for emissions suppression (i.e., water, steam, dry) should also be specified. The vendor shall fully describe the system being proposed, including variations of emissions with all fuels being used, effects over ambient range on emissions and engine power and heat rate. Required utilities for the emission suppression system shall also be addressed. In order for the vendor's response to be complete, the purchaser will specify any site required load variations at given ambient conditions and complete fuel analyses of all fuels to be used. The vendor will take into account any effects caused by the operation of the anti-icing system.

## 5.5.4 Inlet Filters

- **5.5.4.1** The purchaser will specify the type of inlet filtration (for example, inertial-type separator, media filters, self-

cleaning filter, pad-type prefilters, or a combination thereof). If single-stage filtration only is specified, the purchaser will specify if provisions are to be made for the future addition of extra stages.

**5.5.4.2** Unless otherwise specified, a mist eliminator shall be furnished for marine environments.

**5.5.4.3** The vendor's proposal shall include the filtering efficiency and estimated frequency of maintenance of cleaning (or both) for the specified site conditions. The vendor shall also review the specified filtration and comment on the suitability of filtration for the specified machine.

**5.5.4.4** Each filter system requires the following:

- a. An entrance screen to prevent debris or birds from entering the inlet.
  - b. Downward orientation of the air inlet or a louver or cowling to minimize the entry of driving rain, snow, or sand to the filter.
  - c. Walkways, handrails, platforms, and ladders to facilitate access and maintenance.
  - d. Manometer connections and a differential-pressure alarm switch for each stage filtration.
  - e. Wiring in conduit using conduit fittings (with the exception of joints between modules where using flexible conduit is permitted).
  - f. A design that uses bolted and welded fabricated steel plate, reinforced with steel members. The vendor shall furnish all of the supporting structural steel required for the assembled and mounted filter systems. All steel shall be hot-dipped and galvanized, with thickness per ASTM A 123. All external joints shall be seal welded.
  - g. Modular construction with each module fully factory assembled, wired, and plumbed. Each module shall have lifting provisions that permit it to be loaded, unloaded, and lifted into its final assembled position.
  - h. Airtight seams and joints on the clean air side of each filter system.
  - i. Filter assemblies whose clean air side is completely free of loose objects or objects that can become loose during operation.
- **5.5.4.5** When specified, an implosion door shall be provided to prevent excessively high delta pressure in the turbine inlet in the event of filter icing or plugging. This door shall be instrumented to indicate remotely when it is open.
  - **5.5.4.6** Unless otherwise specified, the filter house will be elevated with a minimum 4.6 meter (15 foot) elevation from grade to the lowest part of the filter air entrance. When the filter house is elevated, the vendor shall provide lugs for mounting the house to supporting steelwork. The purchaser shall specify if supporting steel work is to be provided by the vendor.

Note: Consideration should be given to filter units mounted on large horizontal surfaces, such as roofs, to insure adequate clearance from those mounting surfaces even though the filter may be in excess of the specified 4.6 meters (15 feet) above grade.

**5.5.4.7** Sections of the filter house, including door, that require field assembly and welding shall be prefitted in the vendor's shop.

**5.5.4.8** The vendor shall include the following items in his proposal:

- a. Materials of construction and coating.
- b. All performance details.
- c. Weights and dimensions.

## 5.5.5 Inlet and Exhaust Silencers

### 5.5.5.1 Inlet Silencers

**5.5.5.1.1** Silencer attenuation shall meet the noise limitations of 4.1.6.

**5.5.5.1.2** Silencers shall be of welded carbon steel and shall be flanged and sufficiently rigid to be supported only by the end flanges when mounted in a horizontal or vertical duct system.

**5.5.5.1.3** The construction of the silencer baffles shall prevent the baffle packing material from entering the gas stream.

- **5.5.5.1.4** Silencer perforated-plate elements shall be constructed of stainless steel except for elements for use in corrosive environments that may promote stress corrosion cracking. Alternative materials will be specified by the purchaser for corrosive environments.

**5.5.5.1.5** Silencers shall be designed to prevent damage to themselves resulting from acoustical or mechanical resonances or differential thermal expansion.

**5.5.5.1.6** The vendor shall furnish in his proposal the complete details for construction of the silencers; these details shall include a materials description of the acoustical insulation.

**5.5.5.1.7** Lifting provisions for handling shall be incorporated on the silencers.

### 5.5.5.2 Exhaust Silencer

**5.5.5.2.1** Silencer attenuation shall meet the noise limitations of 4.1.6.

**5.5.5.2.2** The basic material for construction of the exhaust silencer shall be hot rolled AISI 1020 or equal for metal service temperatures of  $-25$  to  $455^{\circ}\text{C}$  ( $-13$  to  $851^{\circ}\text{F}$ ). If metal temperatures fall below this range for extended periods, the use of low temperature carbon steel such as ASTM A662 may be used. If metal temperatures exceed  $455^{\circ}\text{C}$  ( $850^{\circ}\text{F}$ ) for

extended periods, use of more corrosion resistant steel shall be provided.

- **5.5.5.2.3** Perforated plates or sheets shall be constructed of 400 series stainless steel except where a corrosive environment may produce stress corrosion cracking.

**5.5.5.2.4** Acoustic and/or thermal insulation, whether externally or internally applied, shall be suitably captured to prevent its deterioration over time when subjected to a normal exhaust system environment.

- **5.5.5.2.5** The exhaust silencer shall incorporate lifting provisions as well as a support interface. The purchaser shall specify exit stack support requirements that will be imposed on the silencer exit flange. This may include not only an exhaust stack but special wind loading or shipping load imposed on the exit flange or silencer support system.

## 5.5.6 Ducting

**5.5.6.1** The duct system shall be arranged so that only the minimum number of changes in direction are made. Turning vanes shall be provided at changes in direction when required to assure uniform flow distribution at the gas turbine flanges, and the leading edge of each vane shall be tapered and smooth. Vanes shall be designed to avoid resonance and shall be attached to the duct by a contiguous weld.

**5.5.6.2** For transition sections between duct components of different cross-sectional areas, the angle between the sides and the axis of the duct should be minimal to reduce pressure drop. In general, the angle should not exceed 15 degrees (0.26 radian).

**5.5.6.3** As a first approximation for the duct design, velocities of 18.3 meters per second (60 feet per second) and 30.5 meters per second (100 feet per second) may be used for the inlet and exhaust, respectively.

**5.5.6.4** Duct supports shall remove all duct loads from the gas turbine flanges. The ducts shall be supported to allow lateral as well as axial growth due to temperature changes. The ducting and supports shall be designed to remain stationary when sections near the gas turbine are removed to provide access for maintenance. Ducts shall be sufficiently rigid to avoid vibration. [Plate 4.8 to 9.5 millimeters ( $\frac{3}{16}$  to  $\frac{3}{8}$  inch) thick is generally used for this purpose.]

**5.5.6.5** Manways shall be provided in each duct adjacent to the gas turbine inlet and exhaust flanges to allow final cleaning and inspection of the entire duct system before operation. These may be the same means of access required by 4.2.7. Manway covers shall be designed to permit their removal at any time without risk of fasteners or other objects being ingested by the gas turbine.

**5.5.6.6** Ducting and casing connection flanges shall be designed so that the stresses imposed, including internal pressure, do not exceed those given in Section VIII of the ASME Code. On the outline drawing, the gas turbine vendor shall indicate the maximum allowable forces and moments on the inlet and exhaust flanges.

**5.5.6.7** For exhaust temperatures greater than 480°C (900°F) at site rated power, special precautions shall be exercised in the selection of duct and silencer materials to avoid carburization or corrosion at these elevated temperatures.

- **5.5.6.8** When specified, an atmospheric relief device shall be provided in the exhaust duct upstream of any isolation damper. (When the atmospheric relief devices and associated dampers are being selected, caution should be exercised regarding the degree of leakage to be tolerated and the location and routing of atmospheric relief discharge.)

**5.5.6.9** The inlet system shall include facilities or provisions for the manufacturer's recommended on-stream cleaning method.

- **5.5.6.10** When specified, emissions sampling ports shall be provided in the exhaust ducting (access ladder and platforms to be provided as necessary).

## 5.5.7 Expansion Joints

**5.5.7.1** Gastight expansion joints shall be provided between the ducting and gas turbine inlet and exhaust flanges. These joints shall accommodate the relative movement of the ducting, regenerator (if any), and gas turbine in vertical and horizontal directions. Expansion joints shall have an internal liner to prevent undue flutter, joint deterioration, or pressure drop. The joints shall be covered with a sound-absorbing material that will meet the noise-level specifications in 4.1.5.

**5.5.7.2** An acceptable inlet joint may be fabricated with canvas that is rubberized on both sides and at least 3 millimeters ( $\frac{1}{8}$  inch) thick.

**5.5.7.3** The exhaust expansion joints shall be of metal or high-temperature fabric. If fabric is used, it shall be multilayered and reinforced with nickel-alloy wires. All bolting, duct, and joint components in contact with the fabric shall have rounded edges to avoid tearing of the material.

## 5.6 INLET COOLERS

### 5.6.1 Evaporative Coolers

- **5.6.1.1** When specified as evaporative, the cooler shall be supplied complete with cooler media, circulation pump, sump drains, and corrosion resistant mist eliminator. The mist eliminator is to minimize moisture carryover into the inlet air stream at 105 percent of maximum engine mass flow and worst case ambient conditions.

**5.6.1.2** Water circulation shutoff shall be controlled with reference to turbine compressor inlet temperature to eliminate any possibility of inlet icing caused by moisture from the evaporative cooler. The minimum temperature is to be determined by the manufacturer, taking all factors into consideration.

**5.6.1.3** All evaporative cooler metallic housing and internal structural support shall be stainless steel. Manways shall be provided for complete access both upstream and downstream of the cooler media and mist eliminator sections.

**5.6.1.4** The housing drainage design shall insure that water does not stand inside the unit at any time. The drainage system shall be designed such that unfiltered air is not allowed to be drawn into the inlet air stream through the drain piping.

- **5.6.1.5** When specified, walkways, handrails, and access ladders shall be provided for access to the manways and other areas of the unit required for servicing.

**5.6.1.6** The vendor shall specify the quality, pH, and quantity of water required to minimize cooler and water system operational problems. The vendor shall advise as to cooler efficiency and as to pressure drop across the cooler system under maximum flow conditions.

## 5.6.2 Inlet Air Cooler Heat Exchanger

- **5.6.2.1** When specified the vendor shall provide a liquid-to-air heat exchanger for the purpose of cooling the inlet air temperature for engine performance enhancement. The cooler section shall be fitted downstream of the inlet filtration system and shall contain a mist eliminator section to eliminate condensed water droplets from entering the air stream.

**5.6.2.2** Construction of the cooler internals shall utilize corrosion resistant materials and optimize thermal efficiency to the greatest extent possible. Details of construction shall be included in the vendor's proposal.

- **5.6.2.3** Purchaser shall specify the following coolant conditions in order for the vendor to properly size the cooler and estimate project performance:

- a. Maximum available flow.
- b. Maximum and minimum temperatures.
- c. Maximum and minimum pressures.
- d. Composition or analysis and cleanliness.

Based on this input, the vendor shall advise in the proposal the pressure drop across the cooler, the performance of the cooler in terms of inlet temperature reduction, as well as effect on turbine shaft output and fuel flow. Additionally, the vendor shall advise all controls being supplied with the cooling system as well as the controls and instrumentation required to be provided by the purchaser.

## 5.7 INSULATION, WEATHERPROOFING, FIRE PROTECTION, AND ACOUSTICAL TREATMENT

### 5.7.1 Insulation

**5.7.1.1** Insulation for personnel protection shall be provided by the vendor. Turbine casings shall be insulated and jacketed or provided with suitable lagging or guards so that no exposed surface exceeds a temperature of 74°C (165°F). Jackets and insulation shall be designed so that routine maintenance may take place without damage being done to the insulation.

- **5.7.1.2** External insulation applied to other portions of the gas turbine installation shall be properly flashed and weatherproofed. The purchaser will specify the extent of insulation for heat conservation to be supplied by the vendor.

**5.7.1.3** Where the application of insulation is not practical or interferes with unit design or operation, barrier isolation such as an enclosure may be utilized (with the approval of the purchaser) to protect personnel from excessive temperature. These barriers must be readily removable for ease of maintenance.

### 5.7.2 Weatherproofing

**5.7.2.1** The gas turbine unit shall be adequate for the degree of weather exposure and for the site and atmospheric conditions specified. For outdoor installations with or without roofs, turbine units and auxiliaries shall be suitable to accommodate the site conditions.

**5.7.2.2** Moisture buildup and corrosion on panel materials shall be minimized. Water or dust leakage through the panel walls or roof seams is unacceptable.

**5.7.2.3** Materials of construction for panels shall be resistant to moisture, fire, insects, vermin, and oil wicking.

### 5.7.3 Fire Protection

A fire protection system shall be furnished when an enclosure is specified by the purchaser or furnished by the vendor, unless specifically deleted from the vendor's scope of supply by the purchaser. The system shall consist as a minimum of the following:

- a. A fire suppression system.
- b. A fire detection system.
- c. A gas detection system for gas fueled units only.

- **5.7.3.1** The fire suppression system shall be designed in accordance with the applicable NFPA standard (NFPA 2001 for clean agent extinguishing systems and NFPA 12 for carbon dioxide extinguishing systems). Alternative systems, such as fire water spray, may be also utilized. The purchaser will specify any special design considerations to be included

in the suppression system, including the specific fire suppression medium.

**5.7.3.2** The primary method of actuation of the suppression system shall be automatic. A manual actuation system is also required. A manual release station shall be located externally on each side of the enclosure. Provisions shall be made for exercising the fire detection and protection system without discharging the fire suppression medium.

- **5.7.3.3** The fire detection system shall be designed in accordance with NFPA 72E. Thermal detection shall be considered the minimum level of detection. Additional levels of detection, such as optical, may be specified by the purchaser.

**5.7.3.4** The gas detection system shall be designed in accordance with NFPA 72E.

**5.7.3.5** All fire suppression and detection devices utilized within the enclosure shall be designed to operate throughout the entire range of operational service conditions encountered within the enclosure.

#### 5.7.4 Acoustical Treatment

- **5.7.4.1** If vendor furnished acoustical treatment is specified, the requirements of 4.1.10 shall apply.
- **5.7.4.2** Any special "far field" or neighborhood sound restrictions that are applicable will be specified.

#### 5.7.5 Enclosures

- **5.7.5.1** When specified, suitable enclosure(s) shall be provided to meet purchaser's acoustical, weatherproofing, safety, and/or fire protection requirements. Enclosure(s) shall be designed to ensure the package can meet the maintenance, operation, and service life requirements. An enclosure system shall consist of the following:

- a. An enclosure surrounding the gas turbine and/or driven equipment.
- b. An enclosure ventilation and purging system.
- c. A fire protection system (see 5.7.3), including enclosure isolation devices.

**5.7.5.2** Enclosures shall be weatherproof per 5.7.2.1 through 5.7.2.3.

**5.7.5.3** Enclosures shall be designed to permit on-site maintenance. The degree of disassembly for maintenance shall be stated in the proposal.

**5.7.5.3.1** Removable roof sections, side panels, or hinged bulkhead walls shall be provided for heavy maintenance. Construction of maintenance accessways shall permit return to the original condition. Caulking or removable portions are not acceptable.

**5.7.5.3.2** Access doors and/or manways shall be provided for routine maintenance and inspection. The sealing devices utilized around the perimeter of these access ways shall be designed to withstand normal use without loss of sealing function.

**5.7.5.3.3** Conduits, fire prevention systems, gas detection, etc., shall not be attached to the underside of the roof or any other panels that must be removed for maintenance.

**5.7.5.4** At least one window shall be supplied on each side of the enclosure, preferably located on an access door and opposite each other. Each window shall be double pane wire reinforced glass with a dead air space between panes.

**5.7.5.5** Unless otherwise specified, lighting for general observation is to be provided within the enclosure. Lights are to be operated by three-way switches located at the access-way on each side of the enclosure.

- **5.7.5.6** The enclosure shall be provided with a fan driven forced ventilation and purging air system designed to provide 100 percent of the ventilation and purging load in the most severe climatic/load conditions. The purchaser will specify fan system redundancy requirements and whether positive or negative pressure is required.

**5.7.5.6.1** Ventilation system will include air filtration and/or silencing equipment if required by the vendor. Ventilation air may be taken from primary air filtration system.

**5.7.5.6.2** The ventilation system shall be designed to handle all specified site climatic or operational conditions.

- **5.7.5.6.3** Ventilation and purging flow shall enter and exit the enclosure via port(s). Each port shall be equipped with a back draft damper and a fire suppression medium damper. The purchaser will specify if additional ventilation ducting is required.

**5.7.5.6.4** If cool down ventilation is required to prevent damage to the gas turbine, auxiliary systems, or instrumentation within the enclosure, a separate DC backup fan shall be provided.

### 5.8 FUEL SYSTEM

#### 5.8.1 General

- **5.8.1.1 Vendor Requirements**

The vendor shall supply a complete system for receiving fuel from the purchaser's system. The fuel system shall be operable with the normal fuel or any alternative or starting fuels. The composition, range of heating values, temperatures, delivery pressures, and contaminant levels will be specified according to 5.8.2 and 5.8.3 in the inquiry specification. The vendor shall advise the purchaser of the effects of contaminants and corrosive agents on turbine operation.

### 5.8.1.2 Fuel Gas System

#### 5.8.1.2.1 A gaseous fuel system shall include:

- a. A "Y" type strainer.
  - b. Necessary instrumentation.
  - c. A manifold and nozzles.
  - d. A fuel shutoff valve with an intermediate vent valve for automatic operation.
  - e. A fuel control valve.
  - f. A fuel gas pressure regulator if required.
  - g. Necessary additional instrumentation.
- **5.8.1.2.2** If the fuel gas pressure required by the vendor is higher than that available, a fuel gas compression system will be furnished by the vendor when specified by the purchaser.
- 5.8.1.2.3** The vendor shall state the maximum and minimum allowable fuel gas temperature supplied by the purchaser.
- **5.8.1.2.4** When specified, twin Y-type strainer(s) with a continuous flow transfer valve shall be mounted off-base and be capable of being cleaned while in operation. The transfer valve shall have a carbon steel body with a stainless steel internals.
  - **5.8.1.2.5** When specified, a fuel bypass valve and vent valve for purging the fuel gas line prior to light off shall be supplied.

### 5.8.1.3 Fuel Gas Piping

**5.8.1.3.1** Gas distribution piping and tubing shall be stainless steel. Use of flexible hoses shall be minimized and, when used, limited to locations where relative movements must be accommodated. All fuel hoses must be made from stainless steel and covered with abrasion resistant braiding. System design must incorporate sufficient separation around each flexible hose at all times to prevent fretting damage to the braiding.

**5.8.1.3.2** Gas distribution piping shall be stainless steel, full penetration butt-welded, and hydrotested.

### 5.8.1.4 Liquid Fuel System

#### 5.8.1.4.1 A liquid fuel system shall include:

- a. Duplex fuel filters with a continuous flow transfer valve if liquid is the primary fuel. A single filter may be supplied if the liquid fuel is not the primary fuel.
- b. Fuel charge pump.
- c. Atomizing air (source to be mutually agreed upon).
- d. Two fuel shutoff valves for automatic operation.
- e. Necessary instrumentation.
- f. Fuel control valve.
- g. Flow dividers (if required by the vendor).
- h. Fuel nozzles and manifold.

**5.8.1.4.2** To prevent coking and plugging, the vendor's design shall include facilities to purge and/or drain liquid fuel from the fuel manifold.

**5.8.1.4.3** When provided, duplex fuel filters shall be accessible with the idle filter capable of being cleaned while in operation. The transfer valve shall have a carbon steel or stainless steel body with stainless steel internals.

- **5.8.1.4.4** If heating of the fuel is required to vaporize and superheat the fuel, or to lower the viscosity to within the manufacturer's limits, heating equipment will be furnished by the purchaser.
- **5.8.1.4.5** If fuel transfer equipment is required, it shall be furnished by the vendor when specified by the purchaser.

### 5.8.1.5 Dual Fuel Operation

- **5.8.1.5.1** When specified, the gas turbine shall be provided with the necessary equipment to permit normal (starting and continuous) operation on either of the fuels, i.e., liquid/gas, liquid/liquid, or gas/gas. The dual fuel system shall provide the capability of automatic transfer from either fuel source to the other fuel source while under full or part load operation. Initiation of the transfer will be a dry contact closure provided by the purchaser.

**5.8.1.5.2** The dual fuel system shall provide smooth, bi-directional fuel transfer without shutdown or interruption of load-carrying ability.

**5.8.1.5.3** When operating on gas fuel, the liquid fuel lines, nozzles, manifolds, etc., shall be automatically purged continuously to prevent plugging and coking.

## 5.8.2 Gaseous Fuel

### 5.8.2.1 Composition

The purchaser will specify the composition of the gas (normal, alternate, or start up) to be supplied. Gas should be dry at the turbine fuel nozzles to prevent over-temperature damage to the turbine due to burning condensate. The vendor shall advise the purchaser if heating is required to maintain the gas above the dew point.

### 5.8.2.2 Contaminants

- **5.8.2.2.1** The contaminants likely to be found in fuel gas depend on the kind of gas involved, such as natural gas, coke oven gas, water gas, producer gas, and refinery gas. Some of the contaminants that are likely to be found include the following:
  - a. Tar, carbon black, and coke.
  - b. Water.
  - c. Solids.
  - d. Naphthalene and gas hydrates.

The concentration of contaminants in the gas will be specified on the data sheets by the purchaser.

**5.8.2.2.2** To alleviate a possibility of liquid contamination, the vendor shall review both the design and off-design operation of the fuel supply system. This review shall include both the vendor's and the purchaser's fuel supply systems.

**5.8.2.2.3** To reduce the potential for damage to the hot-gas-path components, a coalescing filter shall be furnished by the vendor when specified by the purchaser. It shall be sized to keep liquid contents in the fuel gas at or below the maximum levels allowed by the gas turbine manufacturer.

### ● 5.8.2.3 Corrosive Agents

The concentration of hydrogen sulfide, sulfur dioxide, sulfur trioxide, total sulfur, alkali metals, chlorides, carbon monoxide, and carbon dioxide will be specified by the purchaser so that proper precautions can be taken, if necessary, to prevent elevated-temperature corrosion of turbine hot-gas-path components and ambient-temperature corrosion of fuel control valves and systems. (Total sulfur content must also be considered to protect heat-recovery equipment from corrosion.)

### ● 5.8.2.4 Heating Value

The lower heating value of each gas will be specified. During operation, the actual heating value should not differ from the specified value by more than plus or minus 10 percent. For variations in heating value of more than 10 percent, the rate of change will be specified by the purchaser because special equipment may be required for proper fuel control.

## 5.8.3 Liquid Fuel

### 5.8.3.1 Classification

Fuel classifications for gas turbines are listed in ASTM D 2880 and ASTM D 1655:

- a. ASTM D 2880 divides fuel oils into five grades based on their applicability for use in gas turbines. It does not include fuels primarily intended for jet aircraft use.
- b. ASTM D 1655 covers fuels primarily intended for use in jet aircraft. Three types are provided and are differentiated by their flash points, boiling ranges, and freezing points.

### 5.8.3.2 Properties

Both ASTM D 2880 and ASTM D 1655 place limiting values on a number of the properties of the oils in each grade. The properties selected for limitation are those believed to be of the greatest significance in determining performance char-

acteristics of the oils in various gas turbine applications. Other property considerations include the following:

- a. In some instances, mutual agreement on permissible contaminant levels in the fuels to be burned in the gas turbine is required between the interested parties. (This matter is covered in 1.1 of ASTM D 2880, in particular.)
- b. For those cases in which no mutual agreement is reached, the contaminant levels defined as permissible by the gas turbine manufacturer's fuel specification shall apply.
- c. Gas turbine operation and maintenance requirements are benefited when fuels have thermal stability, good combustion quality, and low sulfur and ash content. These qualities become increasingly important when the temperatures of the fuel system and operating turbine are high or when long periods between overhaul are desired.

### ● 5.8.3.3 Grades or Types

The purchaser shall specify which ASTM fuel grades or types or other liquid fuels are to be burned in the gas turbine:

- a. ASTM D 2880 grades:
  1. Grade 0-GT includes naphtha, Jet B, and other light hydrocarbon liquids that characteristically have low flash points and low viscosities compared to those of kerosene and fuel oils.
  2. Grade 1-GT is a light distillate fuel suitable for use in nearly all gas turbines.
  3. Grade 2-GT is a distillate that is heavier than Grade 1-GT, and it can be used by gas turbines not requiring the clean burning characteristics of Grade 1-GT. Fuel heating equipment may be required by the gas turbine depending on the fuel system design or the ambient temperature conditions or both.
  4. Grade 3-GT may be a distillate that is heavier than Grade 2-GT, a residual fuel oil that meets the low ash requirements, or a blend of a distillate and a residual fuel oil. If Grade 3-GT is specified, the gas turbine will require fuel heating in almost every installation.
  5. Grade 4-GT includes most residuals and some topped crudes. Because of the wide variation and lack of control of properties, the gas turbine manufacturer should be consulted about acceptable limits on properties.
- b. ASTM D 1655 types:
  1. Jet A and Jet A-1 are relatively high flash point distillates of the kerosene type. They represent two grades of kerosene fuel that differ only in freezing point.
  2. Jet B is a relatively wide boiling range volatile distillate.
- c. Other types.

The purchaser will furnish a complete analysis for other liquid fuels.

### 5.8.3.4 Effect of Fuel Type

For the fuel specified, the vendor shall state in the proposal the anticipated maximum uninterrupted run time or duration of the fuel system and the hot-gas-path parts.

### 5.8.4 Emission Suppression Systems

- **5.8.4.1** When specified, the gas turbine shall be provided with the necessary equipment for emission suppression for gas-fueled units.
- **5.8.4.2** The purchaser shall specify the site-specific requirements for:
  - a. Emissions levels.
  - b. Power output load range for which these emission level are acceptable.
  - c. Type of emission suppression system required (wet or dry).

Note: *Emission* refers to contaminants in the exhaust stream such as:

- a. NO<sub>x</sub> (oxides of nitrogen).
- b. CO (carbon monoxide).
- c. UHC (unburned hydrocarbons).
- d. Others (sulfur, particulate, etc.).

**5.8.4.3** With purchaser's approval, the level of emissions suppression given in volume part per million (VPPM) of exhaust flow may be allowed to vary within the power range from minimum to maximum load as long as the anticipated yearly load profile yields the required level of emissions output (normally stated in tons/year). By allowing this variance, the complexity of some dry emission suppression systems can be significantly reduced.

- **5.8.4.4** When a wet suppression system is specified, the gas turbine shall be provided with the necessary equipment to permit injection of purchaser-supplied water or steam for emissions suppression.

**5.8.4.4.1** If specified, the supplier shall quote gas turbine performance with and without water/steam injection.

**5.8.4.4.2** Water/steam quality and supply requirements shall be stated in the proposal.

### 5.8.5 Ignition Systems

The ignition system shall include an ignition transformer and igniter plugs. Ignition shall be automatically deenergized, and fuel flow shall be stopped if the turbine fails to fire after a given period.

## 5.9 SPECIAL TOOLS

**5.9.1** 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.

## 6 Inspection, Testing, and Preparation for Shipment

### 6.1 GENERAL

- **6.1.1** The purchaser will specify the extent of participation in this inspection and testing and the amount of advance notification required.

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

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

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

**6.1.5** The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed.

**6.1.5.1** When shop inspection and testing have been specified by the purchaser, the purchaser and the vendor shall meet to coordinate manufacturing hold points and inspector's visits.

**6.1.5.2** *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.

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

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

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

## 6.2 INSPECTION

### 6.2.1 General

- **6.2.1.1** The vendor shall keep the following data available for at least 20 years for examination or reproduction by the purchaser or his representative upon request:
  - a. Necessary certification of material, such as mill test reports.
  - b. Test data to verify that the requirements of the specification have been met.
  - c. Results of documented tests and inspections, including fully identified records of all heat treatment and radiography.
  - d. When specified, final-assembly maintenance and running clearances.
- 6.2.1.2** Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.
- **6.2.1.3** In addition to the requirements of 4.10.4.1, the purchaser may specify the following:
  - a. Parts that shall be subjected to surface and subsurface examination.
  - b. The type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

### 6.2.2 Material Examination

#### 6.2.2.1 General

**6.2.2.1.1** When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is specified, the recommended practices in 6.2.2.2 through 6.2.2.5 shall apply unless other procedures are specified by the purchaser. Cast iron may be inspected in accordance with 6.2.2.4 and 6.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 6.2.2.2 through 6.2.2.5. The material inspection of pressure-containing parts is covered in 4.10.4.5.

Note: These recommended practices describe examination techniques that are applicable to great varieties of sizes and shapes of materials and widely varying examination requirements. Since the specification for the actual component being inspected depends on metallurgy, component configuration, and method of manufacture, specified procedures and acceptance standards for the application should be covered by written standards, developed by the manufacturer for the specific application.

**6.2.2.1.2** Acceptance standards for 6.2.2.2 through 6.2.2.5 shall be mutually agreed upon between the purchaser and the vendor.

#### 6.2.2.2 Radiographic Inspection

Radiographic inspection shall be based upon the procedures of ASTM Standard Practices E 94.

#### 6.2.2.3 Ultrasonic Inspection

Ultrasonic inspection shall be based upon the procedures of ASTM A 609 (castings), ASTM A 388 (forging), or ASTM A 578 (plate).

#### 6.2.2.4 Magnetic Particle Inspection

Both wet and dry methods of magnetic particle inspection shall be based upon the procedures of ASTM Standard Practice E 709.

#### 6.2.2.5 Liquid Penetrant Inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E 165.

### 6.2.3 Mechanical Inspection

- 6.2.3.1** During assembly of the equipment and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another method to remove foreign materials, corrosion products, and mill scale.
- 6.2.3.2** All oil systems furnished shall meet the cleanliness requirements of API Standard 614.
- **6.2.3.3** When specified, the purchaser may inspect for cleanliness the equipment and all piping and appurtenances furnished by or through the vendor before heads are welded to vessels, openings in vessels or exchangers are closed, or piping is finally assembled.
- **6.2.3.4** When specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or heat-affected zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

## 6.3 TESTING

### 6.3.1 General

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

**6.3.1.2** At least 6 weeks before the first scheduled running test, the vendor shall submit to the purchaser, for this review and comment, detailed procedures for all running tests, which include the mechanical running test and all specified running optional tests (see 6.3.4), as well as acceptance criteria for all monitored parameters.

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

notify the purchaser not less than 5 working days before the new test date.

**6.3.1.4** Acceptance of shop tests does not constitute a waiver of requirements to meet field performance under specified operations conditions, nor does inspection relieve the vendor of his responsibilities.

### 6.3.2 Hydrostatic Test

**6.3.2.1** The vendor shall identify in the proposal which components are to be tested hydrostatically.

**6.3.2.2** Parts as identified in 6.3.2.1, piping and auxiliaries, shall be tested hydrostatically with liquid at a minimum of  $1\frac{1}{2}$  times the maximum allowable working pressure but not less than gauge pressure of 1.5 bar (20 pounds per square inch). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

Note: Due to components configuration, pressure gradients, and thermal considerations, the major components of gas turbines such as casings, combustors, ducts etc., are not hydrostatically tested.

**6.3.2.3** 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 of the operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or in Section VIII, Division 1 of the ASME Code for vessels. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

**6.3.2.4** Where applicable, tests shall be in accordance with the ASME Code. In the event that a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

### 6.3.3 Mechanical Running Test

**6.3.3.1** The requirements of 6.3.3.1.1 through 6.3.3.1.12 shall be met before the mechanical running test is performed.

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

**6.3.3.1.2** All oil pressures, viscosities, and temperatures shall be at the same operating values recommended in the manufacturer's operating instructions for the specific unit under test. Oil flow rates through the entire operational speed range of gas turbine train shall be determined. The purchaser and the vendor shall mutually agree on an acceptable method of measurement.

**6.3.3.1.3** All joints and connections shall be checked for tightness and any leaks shall be corrected. Casing air leaks, according to the judgment of the purchaser, are permissible if they do not adversely affect the specified performance or pose a safety hazard.

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

**6.3.3.1.5** Testing with the contract coupling is preferred. If this is not practical, the mechanical running test shall be performed with coupling-hub idling adapters in place, resulting in moments equal ( $\pm 10$  percent) to the moment of the contract coupling hub plus one-half that of the coupling spacer.

**6.3.3.1.6** The auxiliary systems mounted on the turbine main base shall be tested with the turbine during the mechanical run. These auxiliary systems may include but are not limited to the job oil system(s), fuel systems, starting and cooldown drive systems, atomizing liquid fuel system, and auxiliary gear box.

**6.3.3.1.7** Auxiliary systems mounted on a separate auxiliary base (other than the main base) may be tested separately. All auxiliary systems, including the control panel, shall be shop tested to confirm satisfactory field operation. Details of the tests shall be developed jointly by the purchaser and the vendor.

Note: The inlet system, deciding systems, exhaust system, sound enclosure, and fire protection system are generally not tested during the mechanical run. They may be included in the complete package operation test (refer to 6.3.4.2.1).

**6.3.3.1.8** Oil filtration during the test shall be 10-microns nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of API Standard 614 before any test is started.

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

**6.3.3.1.10** When included in the contract equipment, instrumentation with the capability of continuously monitoring and plotting revolutions per minute peak-to-peak displacement and phase angle ( $x-y-\dot{y}$ ) shall be used during the test. Presentation of vibration displacement and phase marker shall also be by oscilloscope.

**6.3.3.1.11** The vibration characteristics determined by the use of the instrumentation specified in 6.3.3.1.9 and

6.3.3.1.10 shall serve as the basis for acceptance or rejection of the machine (see 4.7.4.5).

**6.3.3.1.12** When seismic test values are specified, vibration data (minimum and maximum values) shall be recorded and located (clock angle) in a radial plane transverse to each bearing centerline (if possible), using shop instrumentation during the test.

**6.3.3.2** Unless otherwise specified, the mechanical running test of the equipment shall be conducted as specified in 6.3.3.2.1 through 6.3.3.2.5.

**6.3.3.2.1** The equipment shall run at idle speed until the bearing and lube-oil temperatures have reached the operating range specified by the vendor and the shaft vibrations have stabilized. The unit will then be accelerated to minimum governor and operated at 10 percent speed increments from minimum governor to maximum continuous speed. The unit shall be allowed to stabilize at each speed increment.

Note: Caution should be exercised when operating equipment at or near critical speeds.

**6.3.3.2.2** The output speed shall be increased to one percent below trip speed, and the equipment shall be run for a maximum of 15 minutes (see 4.7.4.5).

**6.3.3.2.3** Overspeed trip devices shall be checked and adjusted until valves within one percent of the minimal trip setting are attained. Mechanical overspeed devices, if included, shall attain three consecutive nontrending trip values.

**6.3.3.2.4** When utilized for the test, 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. As a minimum, the following data shall be recorded for governors: sensitivity and linearity of relationship between speed and control signal and, for adjustable governors, response to the control signal shall be checked.

**6.3.3.2.5** The speed shall be adjusted to the maximum continuous speed, and the equipment shall be run for 4 hours, unless otherwise agreed.

**6.3.3.3** The requirements of 6.3.3.3.1 through 6.3.3.3.5 shall be met during the mechanical running test.

**6.3.3.3.1** During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured vibration shall not exceed the limits of 4.7.4.5 and shall be recorded throughout the operating speed range.

**6.3.3.3.2** While the equipment is operating at maximum continuous speed and at other speeds that may have been

specified in the test agenda, sweeps shall be made for vibration amplitudes and frequencies other than synchronous. As a minimum, these sweeps shall cover a frequency range from 0.25 to 8 times the maximum continuous speed but not more than 90,000 cycles per minute (1,500 hertz). If the amplitude of any discrete, nonsynchronous vibration exceeds 20 percent of the allowable vibration as defined in 4.7.4.5, the purchaser and the vendor shall mutually agree on requirements for any additional testing and on the equipment's suitability for shipment.

**6.3.3.3.3** For a prototype or modified G.T. model, the mechanical running test shall verify that lateral critical speeds conform to the requirements of 4.7.2.

For flexible-shaft machines, the first lateral critical speeds shall be determined during the mechanical running test.

- **6.3.3.3.4** When specified plots showing synchronous vibration amplitude and phase angle versus speed for deceleration shall be made before and after the 4 hour run. Plots shall be made of both the filtered (one per revolution) and the unfiltered vibration levels. When specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be 400 to the specified driver trip speed.

**6.3.3.3.5** For a prototype or modified G.T. model, shop verification of the unbalanced response analysis shall be performed in accordance with Appendix D.

- **6.3.3.3.6** When specified, tape recordings shall be made of all real-time vibration data (Item 32, Appendix C). The tape recordings of the real-time vibration data shall be given to the purchaser.

**6.3.3.4** Unless otherwise specified, the requirement of 6.3.3.4.1 through 6.3.3.4.2 shall be met after the mechanical running test is completed.

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

**6.3.3.4.2** 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.

## ● 6.3.4 Optional Tests

When specified, the shop tests described in 6.3.4.1 through 6.3.4.11 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

#### ● 6.3.4.1 Performance Test

The machine shall be tested in accordance with ASME Power Test Codes 1 and 22, as specified by the purchaser.

#### ● 6.3.4.2 Complete-Unit Test

Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. When specified, torsional vibration measurements shall be made to verify the vendor's analysis. The complete unit test shall be performed in place of or in addition to separate tests of individual components specified by the purchaser.

#### ● 6.3.4.2.1 Package Test

When specified to minimize the operation required during the commissioning on site, the main contract auxiliary systems mounted on separate base shall also be used during the mechanical running test. These systems may include:

- a. Control panel.
- b. Auxiliary gear.
- c. Starting equipment.
- d. Lube-oil system.
- e. Hydraulic oil system.
- f. Gas fuel system.
- g. Liquid fuel system.
- h. Atomizing air system.
- i. Entel system.
- j. Exhaust system.
- k. Enclosure with the associated equipment.
- l. Fire protection.
- m. De-icing.

Note: The scope of this test shall be developed jointly by the purchaser and the vendor. This test is recommended for units to be installed in locations where the commissioning operations could be particularly difficult or expensive.

#### ● 6.3.4.3 Gear Test

The gear shall be tested with the gas turbine unit during the mechanical running test.

#### ● 6.3.4.4 Sound-Level Test

The sound-level test shall be performed in accordance with the ANSI B133.8. In the event that overall sound pressure levels are not satisfied, diagnostic testing will be performed to determine the sound power levels of each principal noise source in accordance with ISO-10494.

#### ● 6.3.4.5 Auxiliary-Equipment Test

Auxiliary equipment, such as oil systems and control systems, shall be tested in the vendor's shop. Details of the auxil-

iary equipment tests shall be developed jointly by the purchaser and the vendor.

#### ● 6.3.4.6 Post-Test Inspection

The gas turbine shall be inspected after satisfactory completion of the running test. Complete dismantling, inspection, and reassembling shall be required if the mechanical running test is unsatisfactory.

#### ● 6.3.4.7 Inspection of Hub/Shaft Fit for Hydraulically Mounted Couplings

After the running tests, the shrink fit of hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.

#### ● 6.3.4.8 Governor Response and Emergency Overspeed Trip Systems Tests

**6.3.4.8.1** The response time of the speed governing systems shall be strip-chart recorded to confirm compliance with the maximum speed rise requirements of 5.4.3.5.

**6.3.4.8.2** The response time of the emergency overspeed trip systems shall be strip-chart recorded to confirm compliance with 5.4.4.2, Item b.

#### ● 6.3.4.9 Spare Parts Test

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

#### ● 6.3.4.10 Fire Protection Tests

The fire protection systems shall comply with NFPA requirements.

#### ● 6.3.4.11 Other Tests and Inspections

Other tests and inspections not listed or defined in this standard are to be completely described in the inquiry and the order.

### 6.4 PREPARATION FOR SHIPMENT

- **6.4.1** The gas turbine units shall be suitably prepared for the type of shipment specified, including blocking of the rotors when necessary. Blocked rotors shall be identified by corrosion resistant tags externally attached with stainless steel wire. 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. Any gas turbine

component accessory, or instrument not suitable for the extremes of temperature that can be expected during shipment or storage, shall be identified by the vendor in the proposal.

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

**6.4.3** The equipment shall be prepared for shipment after all testing and inspections have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 6.4.3.1 through 6.4.3.11.

**6.4.3.1** Exterior surfaces, except for machine surfaces and corrosion-resistant material, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.

**6.4.3.2** Exterior machined surfaces, except for corrosion resistant material, shall be coated with a suitable rust preventative.

**6.4.3.3** The interior of the equipment shall be clean, free from scale, welding spatter and foreign objects, and treated with a suitable rust preventative in accordance with manufactured standard. Product removal requirements prior to start up shall be identified by external tags.

**6.4.3.4** Internal steel areas of bearing housings and carbon steel oil systems' auxiliary equipment, such as reservoirs, vessels and piping, shall be coated with an oil-suitable rust preventative. In addition, bearing assemblies shall be fully protected from the entry of moisture and dirt.

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

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

Note: These are shipping plugs; permanent plugs are covered in 4.4.4.

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

**6.4.3.8** Lifting points and the center of gravity shall be clearly identified on the equipment package. A recommended lifting arrangement shall be provided by the vendor.

**6.4.3.9** The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion resistant metal tags indicating

the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one on the inside and one on the outside of the shipping container.

**6.4.3.10** When a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 3 years. The rotor shall be treated with a rust preventative and shall be housed in a vapor-barrier envelope with a low-release volatile-corrosion inhibitor. The rotor shall be crated for domestic or export shipment, as specified. A purchaser-approved resilient material 3.0 millimeters ( $1/2$  inch) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)] shall be used between the rotor and the crude at the support areas. The rotor shall not be supported at journals.

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

**6.4.4** Components (both individual pieces and packages sets) shipped with mounted preassembled piping, tubing or wiring shall comply with the requirements of the Occupational Safety and Health Administration.

**6.4.5** Auxiliary piping connections furnished on the purchased equipment shall be identified by the relevant drawing and list.

**6.4.6** If vapor corrosion inhibitors in bags are installed in large cavities to absorb moisture, the bags must be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers, and bag locations shall be indicated on corrosion resistant tags attached with stainless steel wire.

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

**6.4.8** Connections on auxiliary piping removed for shipment shall be matchmarked for ease of reassembly.

**6.4.9** When specified, the fit-up and assembly of machine mounted piping, intercoolers, and so forth shall be completed in the vendor's shop prior to shipment.

## 7 Vendor's Data

### 7.1 GENERAL

**7.1.1** The information to be furnished by the vendor is specified in 7.2 and 7.3. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix B) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the proposal or order, as well as the number and type of copies required by the purchaser.

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

- a. The purchaser's/user's corporate name.
- b. The job/project number.
- c. The equipment service name and item number.
- d. The inquiry or purchase order number.
- e. Any other identification specified in the inquiry or purchase order.
- f. The vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

**7.1.3** A coordination meeting shall be held, preferably at the vendor's plant, within 4 to 6 weeks after the purchase commitment. Unless otherwise specified, the vendor will prepare and distribute an agenda prior to this meeting, which, as a minimum, will include review of the following items:

- a. The purchase order, scope of supply, unit responsibility, and subvendor items.
- b. The data sheets.
- c. Applicable specifications and previously agreed upon exceptions.
- d. Schedules for transmittal of data, production, and testing.
- e. The quality assurance program and procedures.
- f. Inspection, expediting, and testing.
- g. Schematics and bills of material (B/M) of auxiliary systems.
- h. The physical orientation of the equipment, piping, and auxiliary systems.
- i. Coupling selections.
- j. Thrust-bearing sizing and estimated loading.
- k. The rotor dynamic analysis.
- l. Other technical items.

## 7.2 PROPOSALS

### ● 7.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall contain the data specified in 7.2.2 through 7.2.5 as well as a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified per 7.1.2.

## 7.2.2 Drawings

**7.2.2.1** The drawings indicated on the Vendor Drawing and Data Requirements form shall be included in the proposal. As a minimum, the following data shall be furnished:

- a. A general arrangement or outline drawing for each major skid or system, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and maximum maintenance weights (indicated for each piece). The direction of rotation and the size and location of major purchaser connections shall also be indicated.
- b. Cross-sectional drawings showing details of the gas turbine proposed.
- c. Schematics of all auxiliary systems, such as fuel, lube-oil, water/steam injection, control, and electrical systems. Bills of material shall be included.
- d. Methods of lifting the assembled machine or machines and major components. (This information may be included on the drawings specified in Item a above.)

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

## 7.2.3 Technical Data

The following technical data shall be included:

- a. The purchaser's data sheets with complete vendor's information entered thereon and literature that fully describes the details of the offering.
- b. The purchaser's noise data sheet.
- c. The Vendor Drawing and Data Requirements form (see Appendix B) indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.
- d. A schedule for the shipment of the equipment, in weeks after receipt of the order.
- e. A list of major wearing components showing interchangeability with other purchaser units.
- f. A list of spare parts recommended for start up and normal maintenance purposes.
- g. A list of special tools furnished for maintenance. Any metric items included in the offering shall be identified.
- h. A statement of any special weather protection and winterization required for start up, operation, and periods of idleness under the various site conditions specified on the data sheets. The list should show the protection to be furnished by the purchaser, as well as the protection that is included in the vendor's scope of supply.
- i. A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas, and lube oil, including the quantity of lube oil required and the supply pressure, the heat load to be removed by the oil, and the

nameplate power rating, operating power rating, and operating power requirements of auxiliary drivers. Approximate data shall be defined and clearly identified as such.

j. A list of materials of construction of components in contact with purchaser specified corrosive agents as described in 4.10.1.1.

k. A description of the tests and inspection procedures for materials as required by 4.10.1.3.

l. A description of special requirements, as outlined in the purchaser's inquiry and in 4.1.3, 4.1.4, 4.1.6, 4.1.11, 4.3.2, 4.3.4, 4.5.3.1, 4.9.2, 4.9.5, 4.10.1.1, 4.10.1.2, 4.10.1.3, 5.5.5.1.6, 5.5.5.8, 5.5.6.3, 5.5.6.8, 5.8.3.4, 6.4.1, and any other paragraph in the purchaser's inquiry.

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

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

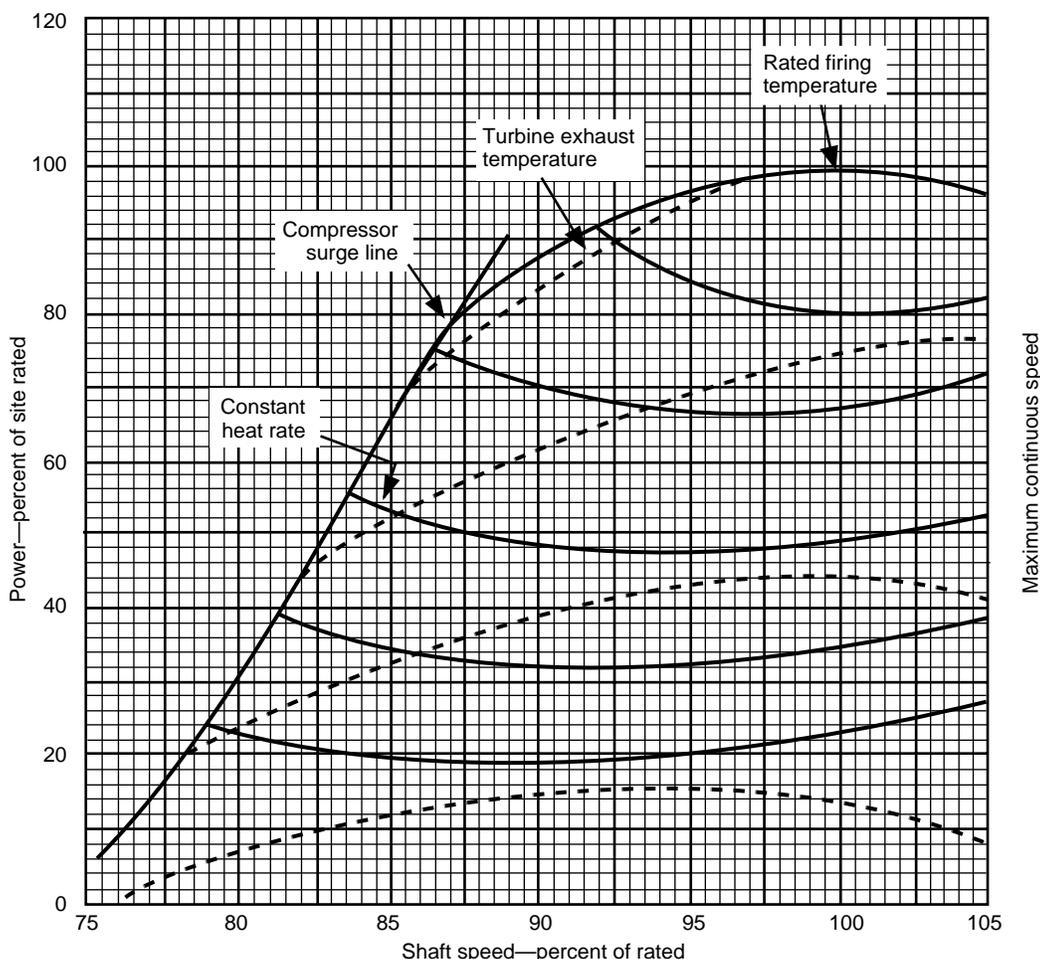
o. Vendor standard vibration limits. In addition, the criteria used to establish the quoted limits shall be listed (see 4.7.4.5).

## 7.2.4 Curves

The proposal shall contain a power output versus speed curve for the rated site conditions. It should follow the formats shown in Figures 2, 3, or 4, as applicable. Additional curves shall be presented showing site rated power and speed at specified maximum and minimum site ambient temperatures and showing both using specified fuels. All curves shall include power deductions (or fuel increases) for inlet and exhaust pressure losses to reflect the inlet and exhaust equipment that is specified or proposed. When specified, the curves described in Items a through d below shall also be furnished:

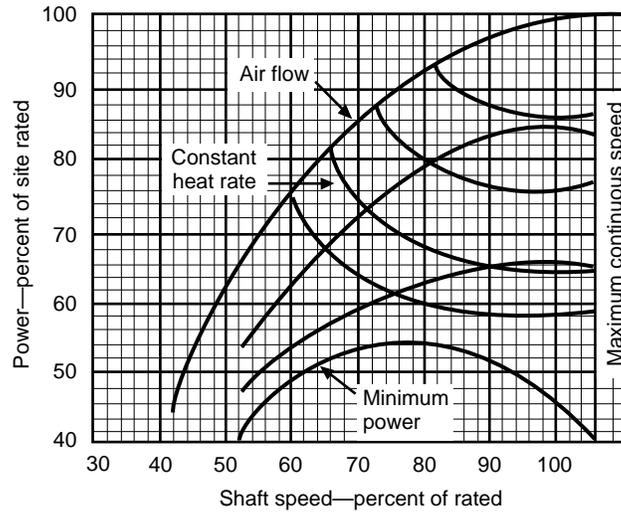
a. A speed/torque curve for the power-output shaft. For single shaft designs, the required starting torque and the combined torque to load produced by the starting device plus the turbine after light off shall be indicated.

b. Curves showing the incremental power output for increments of steam or water injection. The purchaser will state the quantity and condition of injection steam available.



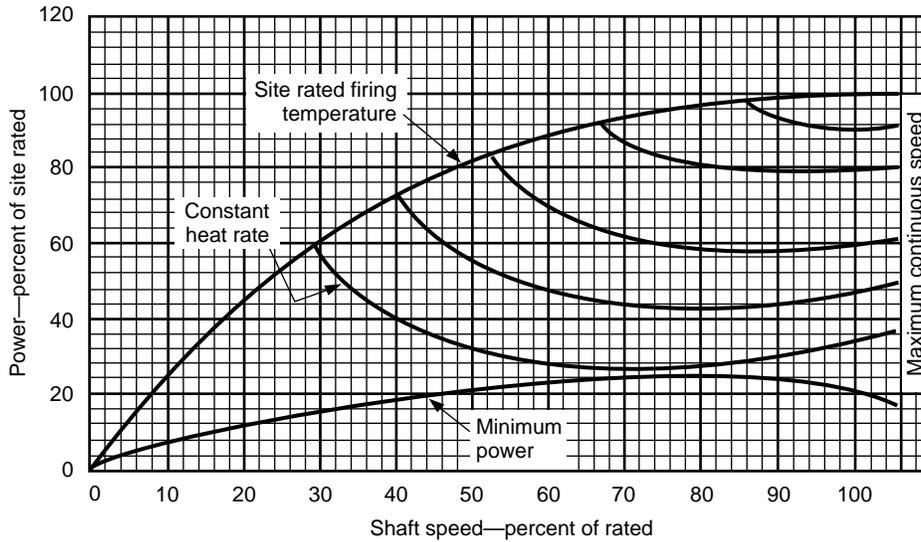
Note: Rated site conditions are as follows: inlet pressure loss (in water), exhaust pressure loss (in water), inlet air temperature (in °F), and atmospheric pressure (in pounds per square inch absolute).

Figure 2—Performance Curves for a Single Shaft Gas Turbine



Note: Rated site conditions are as follows: inlet pressure loss (in water), exhaust pressure loss (in water), inlet air temperature (in °F), and atmospheric pressure (in pounds per square inch absolute).

Figure 3—Performance Curves for a Multiple Shaft Gas Turbine (Constant Exhaust Temperature)



Note: Rated site conditions are as follows: inlet pressure loss (in water), exhaust pressure loss (in water), inlet air temperature (in °F), and atmospheric pressure (in pounds per square inch absolute).

Figure 4—Performance Curves for a Multiple Shaft Gas Turbine (Varying Exhaust Temperature)

- c. Curves showing the effect of full-range ambient conditions on exhaust flow and temperature.
- d. Run-down curves showing exhaust flow and temperature versus time after trip, under full load and no load initial conditions.

### 7.2.5 Options

**7.2.5.1** The vendor shall furnish a list of the procedures for any special or optional tests that have been specified by the purchaser or proposed by the vendor.

**7.2.5.2** When a gas turbine is flat-rated, the vendor shall advise the impact on parts life and required inspections.

## 7.3 CONTRACT DATA

### 7.3.1 General

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

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

**7.3.1.3** A complete list of all vendor data shall be included with the first issue of major drawings. This list will contain titles, drawing or document numbers, and a schedule for transmission of all data the vendor shall furnish. The drawing or data titles shall be cross-referenced as closely as is practical to the corresponding items in Appendix B.

### 7.3.2 Drawings

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

### 7.3.3 Technical Data

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

### 7.3.4 Progress Reports

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

### 7.3.5 Parts Lists and Recommended Spares

**7.3.5.1** The vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include manufacturer's unique part numbers and materials of construction. Materials shall be identified as specified in 4.10.1.2. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the purchaser may determine the interchangeability of the part with other equipment. Parts that have been modified from standard dimensions and/or finished to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items shall be identified by the original manufacturer's name and part number.

**7.3.5.2** The vendor shall indicate on the above parts lists which parts are recommended spares for start up and normal maintenance (see Item f of 7.2.3). The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start up. The transmittal letter shall be identified with the data specified in 7.1.2.

### 7.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

#### 7.3.6.1 General

The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference-identifying data specified in 7.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation.

#### 7.3.6.2 Installation Manual

Any special information required for proper installation design that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time that is mutually agreed upon in the order but not later than the final issue of prints. The manual shall contain information such as special alignment and grouting procedures, utility specifications (including quantities), and all other installation data, including the drawings and data specified in 7.3.2 and 7.3.3. The manual(s) shall clearly identify the locations of all lifting

points and lifting lugs. Weights, dimensions, and centers of gravity shall be readily identifiable. Where necessary instructions, drawings, data, procedures or other means for the safe handling, loading, unloading, and maintenance of that package shall also be included.

### 7.3.6.3 Operating and Maintenance Manual

Manual(s) containing operating and maintenance data shall be forwarded at a time mutually agreed upon by the purchaser and the vendor, but no later than shipment. One manual shall accompany each unit at shipment. This manual shall include a section that provides special instructions for operation at

specified extreme environmental conditions, such as temperatures. The manual shall include centers of gravity and rigging provisions to permit the removal of the top half of casings, rotors, and any subassemblies that weigh more than 300 pounds (135 kilograms). As a minimum, the manual shall also include all the data listed in Appendix B.

### ● 7.3.6.4 Technical Data Manual

When specified, a technical data manual shall be provided at a time mutually agreed upon by the purchaser and the vendor. (See Appendix B for detail requirements.)

## APPENDIX A—TYPICAL DATA SHEETS





**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 2 OF 10 BY \_\_\_\_\_

**FUEL SYSTEM (5.8)**

2 TYPE  GAS (5.8.2)  LIQUID (5.8.3)  DUAL (5.8.1.5.1)  
 3 **DUAL SYSTEM REQMTS** (5.8.1.5.1)  GAS/GAS  GAS/LIQUID  LIQUID/LIQUID  
 4  COMPLETE FUEL RECEIVING SYSTEM (5.8.1.1)  MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER \_\_\_\_\_ SECONDS

**GAS FUELS (5.8.2)**

**LIQUID FUELS (5.8.3)**

9  FUEL ANALYSIS - MOL % (5.8.2.1)  
 10 COMPOSITION: M.W. NORMAL STARTING ALT  
 11 AIR 29 \_\_\_\_\_  
 12 OXYGEN 32 \_\_\_\_\_  
 13 NITROGEN 38 \_\_\_\_\_  
 14 WATER VAPOR 18 \_\_\_\_\_  
 15 CARBON MONOXIDE 28 \_\_\_\_\_  
 16 CARBON DIOXIDE 44 \_\_\_\_\_  
 17 HYDROGEN 2 \_\_\_\_\_  
 18 METHANE 16 \_\_\_\_\_  
 19 ETHYLENE 26 \_\_\_\_\_  
 20 ETHANE 30 \_\_\_\_\_  
 21 PROPYLENE 42 \_\_\_\_\_  
 22 PROPANE 44 \_\_\_\_\_  
 23 I-BUTANE 58 \_\_\_\_\_  
 24 A-BUTANE 58 \_\_\_\_\_  
 25 I-PENTANE 72 \_\_\_\_\_  
 26 A-PENTANE 72 \_\_\_\_\_  
 27 HEXANE PLUS \_\_\_\_\_  
 28 \_\_\_\_\_  
 29 TOTAL \_\_\_\_\_  
 30 AVG. MOL. WT. \_\_\_\_\_  
 31 CORS AGNTS (5.8.2.3) PPM \_\_\_\_\_  
 32 CONTMNTS (5.8.2.2.1) PPM \_\_\_\_\_  
 33 LHV MJ/m<sup>3</sup>/HR (5.8.2.4) \_\_\_\_\_  
 34 FUEL PRESS.MAX/MIN, kPag \_\_\_\_\_  
 35 FUEL TEMPERATURE MAX/MIN, °C \_\_\_\_\_  
 36  FUEL PRESSURE REQUIRED  
 37 MAXIMUM/MINIMUM, kPag \_\_\_\_\_  
 38 COMPRESSION SYS REQD (5.8.1.2.2)  YES  NO  
 39 HEATER REQD (5.8.2.1)  YES  NO  
 40  RATE OF CHANGE OF LHV (5.8.2.4) \_\_\_\_\_

**FUEL GRADE (5.8.3.3)**  
 ASTM D1655 ASTM  0GT  1GT  
 JET  A  A-1  B D2880  2GT  3GT  4GT  
 OTHER, INDICATE ANALYSIS BELOW (5.8.3.3 c)  
 LIQUID FUEL TREATMENT REQUIRED  YES  NO  
 TREATMENT SYSTEM BY  VENDOR  OTHER \_\_\_\_\_  
 FUEL TRANSFER EQUIP REQUIRED (5.8.1.4.5)  YES  NO  
 HEATER REQUIRED (5.8.1.4.4)  YES  NO  
 LIQUID FUEL PRESS REQUIRED, MAX/MIN, kPag \_\_\_\_\_  
**FUEL ANALYSIS DATA (5.8.3.3)** ASTM METHOD MEASURED VALUE  
**PROPERTY**  
 VISCOSITY, SSU @ 38°C D-445 \_\_\_\_\_  
 DISTILLATION DATA D-86 \_\_\_\_\_  
 50% RECOVERY, °C MAX \_\_\_\_\_  
 END POINT, °C MAX \_\_\_\_\_  
 SULFUR CONTENT %WEIGHT, MAX. (SELECT APPL. METHOD)  
 BOMB METHOD D-129 \_\_\_\_\_  
 LAMP METHOD D-1266 \_\_\_\_\_  
 HIGH-TEMP METHOD D-1552 \_\_\_\_\_  
 CARBON RESIDUE (ON 10%  
 BOTTOMS) % WT. MAX. \_\_\_\_\_  
 CONRADSON D-189 \_\_\_\_\_  
 RAMSBOTTOM D-524 \_\_\_\_\_  
 COPPER STRIP CORROSION PLATE D-130 \_\_\_\_\_  
 3 HOURS AT 100°C MAXIMUM  
 AROMATIC CONTENT D-1319 \_\_\_\_\_  
 ASH CONTENT D-482 \_\_\_\_\_  
 SPECIFIC GRAVITY, 15°C D-1298 \_\_\_\_\_  
 FLASH POINT, °C D-56 \_\_\_\_\_  
 POUR POINT, °C D-97 \_\_\_\_\_  
 WATER D-95 \_\_\_\_\_  
 FILTERABLE DIRT, MG/100ML D-2276 \_\_\_\_\_  
 TRACE METALS (ATOMIC  
 ABSORPTION PREFERRED) D-3605 \_\_\_\_\_  
 SODIUM \_\_\_\_\_  
 POTASSIUM \_\_\_\_\_  
 VANADIUM \_\_\_\_\_  
 CALCIUM \_\_\_\_\_  
 LEAD \_\_\_\_\_  
 OTHER METALS \_\_\_\_\_  
 LOWER HEATING VALUE, MJ/kg D-2382 \_\_\_\_\_

42 **REMARKS:** \_\_\_\_\_  
 43 \_\_\_\_\_  
 44 \_\_\_\_\_  
 45 \_\_\_\_\_  
 46 \_\_\_\_\_

**FUEL SYSTEM PIPING**

49  BY PASS AND VENT VALVE (3.7.1.3)  ISOLATION BLOCK VALVES  ANSI FLANGE RATING  
 50  TWIN Y-TYPE STRAINER WITH CONTINUOUS FLOW  NACE MATERIAL STANDARDS (4.10.1.8)  
 51  TRANSFER VALVE (5.8.1.2.4)  
 52

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 3 OF 10 BY \_\_\_\_\_

**CONSTRUCTION FEATURES (NOTE 1)**

**MATERIALS OF CONSTRUCTION (4.10)**

SPEEDS:

3 MAX. CONT. \_\_\_\_\_ RPM TRIP \_\_\_\_\_ RPM

LATERAL CRITICAL SPEEDS (DAMPED)

5 FIRST CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE

6 SECOND CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE

7 THIRD CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE

8 FOURTH CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE

PROTOTYPE OR MODIFIED ROTOR SUPPORT (4.7.3.5)

10  TRAIN LATERAL ANALYSIS REQUIRED (D.1.3)

11  TRAIN TORSIONAL ANALYSIS REQUIRED (2.7.4.5)

12  TORSIONAL CRITICAL SPEEDS:

13 FIRST CRITICAL \_\_\_\_\_ RPM

14 SECOND CRITICAL \_\_\_\_\_ RPM

15 THIRD CRITICAL \_\_\_\_\_ RPM

16 FOURTH CRITICAL \_\_\_\_\_ RPM

17 **VIBRATION:** (4.7.4.5) (7.2.3 o):

18  ALLOWABLE TEST LEVEL: SHAFT \_\_\_\_\_ MICRONS P/P

19 \_\_\_\_\_ CASE \_\_\_\_\_ mm/SEC

20  ROTATION, VIEWED FROM DRIVE END  CW  CCW

COMPRESSOR ROTOR BLADES \_\_\_\_\_

COMPRESSOR STATOR VANES \_\_\_\_\_

SHAFT \_\_\_\_\_ BLADE/VANE COATING \_\_\_\_\_

TURBINE STAGE	NOZZLES	BLADES	WHEELS OR DISCS
1			
2			
3			
4			

COMBUSTORS \_\_\_\_\_

COMPRESSOR CASING \_\_\_\_\_

COMBUSTOR CASING \_\_\_\_\_

TURBINE CASING \_\_\_\_\_

21 **AIR COMPRESSOR:**

22 STAGES \_\_\_\_\_ MAXIMUM TIP SPEED \_\_\_\_\_ m/SEC

23 TYPE \_\_\_\_\_ PRESSURE RATIO \_\_\_\_\_

24 **CASING SPLIT** (2.2.3)  AXIAL  RADIAL

25 ROTOR  SOLID  BUILT UP

26 **TURBINE:**

27 STAGES \_\_\_\_\_ MAX. TIP SPEED \_\_\_\_\_ m/SEC

28 **CASING SPLIT** (4.2.3)  AXIAL  RADIAL

29 ROTOR  SOLID  BUILT UP

**GAUGE BOARDS AND CONTROL PANELS**

**GAUGE BOARDS**

LOCATION \_\_\_\_\_

CONTROL CONSOLES (5.4.5.1.1)  ON-SKID  OFF SKID LOCAL

OFF SKID REMOTE

WEATHER PROTECTION REQUIRED  YES  NO

SPECIFICATION \_\_\_\_\_

ANNUNCIATOR REQUIRED (5.4.4.8.5)

VISUAL DISPLAY UNIT (VDU)  KEYBOARD

30 **COMBUSTORS:** (4.3.2)

31  SINGLE  MULTIPLE, NUMBER \_\_\_\_\_

32  GAS  LIQUID  DUAL FUEL

33 MAXIMUM ALLOWABLE TEMP. VARIATION \_\_\_\_\_ °C

34 APPLICABLE PLANE \_\_\_\_\_

35 FUEL NOZZLES PER COMBUSTOR \_\_\_\_\_

36  WOBBE INDEX NO REQD (4.3.7)  MAX \_\_\_\_\_ MIN \_\_\_\_\_

**CONTROL SYSTEMS**

TYPE (5.4.1.5)

MECH  PNEU  HYDRA  ELECTRIC  ELECTRONIC

MICROPROCESSOR BASED  COMBINED \_\_\_\_\_

SIGNAL SOURCE \_\_\_\_\_

SENSITIVITY \_\_\_\_\_  RANGE \_\_\_\_\_ TO \_\_\_\_\_

TIME OF AC OUTAGE PROTECTION \_\_\_\_\_ MIN (5.4.1.6)

SHUT OFF VALVES FOR SHUT DOWN SENSORS (5.4.4.9)

STARTING SYSTEM (5.4.2.1)

MANUAL  SEMI AUTOMATIC  AUTOMATIC

PURGE (5.4.2.2) \_\_\_\_\_ MINUTES

SEPARATE SHUTDOWN VALVE TEST DURING OPERATION

37 **MAINTENANCE INTERVALS, HOURS**

38  HOT GAS PATH INSPECTIONS \_\_\_\_\_

39  MAJOR OVERHAULS \_\_\_\_\_

40  OTHER \_\_\_\_\_

41

42 align="center">**GOVERNOR (5.4.3)**

43  MFR'S STD.  OTHER  MAKE \_\_\_\_\_  MODEL \_\_\_\_\_

44  CONSTANT SPEED  VARIABLE SPEED

45  ISOCHRONOUS  DROOP

46 REMOTE SHUTDOWN SIGNAL  ELECTRIC

47  PNEUMATIC  HYDRAULIC  NONE

48 MANUAL SPEED CHANGER, RPM \_\_\_\_\_ MAX. \_\_\_\_\_ MIN.

49  MAINTAIN TURBINE SPEED UPON FAILURE OF CONTROL

50 SIGNAL OR ACTUATOR \_\_\_\_\_

**NOTE (1)** FOR MULTIPLE SHAFT TURBINES, COMPLETE ALL APPLICABLE PORTIONS FOR EACH SHAFT.

**REMARKS:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Obtained from GLOBAL ENGINEERING DOCUMENTS  
 15 Inverness Way E. Englewood, CO 80112 (303)397-7956 (800)854-7179  
 <OPTION name="EXPANSION" />

<OPTION name="SESSION" />

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 4 OF 10 BY \_\_\_\_\_

**CONSTRUCTION FEATURES CONTINUED (NOTE 1)**

**BEARINGS AND BEARING HOUSINGS (4.8)**

3	RADIAL (NOTES 2 AND 3)	INLET	EXHAUST	THRUST (NOTE 3)	ACTIVE	INACTIVE
4	<input type="checkbox"/> TYPE			<input type="checkbox"/> TYPE		
5	<input type="checkbox"/> MANUFACTURER			<input type="checkbox"/> MANUFACTURER		
6	<input type="checkbox"/> LENGTH, mm			<input type="checkbox"/> UNIT LOAD (ULTIMATE), kPa		
7	<input type="checkbox"/> SHAFT DIAMETER, mm			<input type="checkbox"/> UNIT LOAD (SITE RATED), kPa		
8	<input type="checkbox"/> UNIT LOAD (ACT/ALLOW), kPa	/	/	<input type="checkbox"/> UNIT LOAD (MAX POTEN.), kPa		
9	<input type="checkbox"/> BASE MATERIAL			<input type="checkbox"/> NO. OF PADS/AREA, (cm <sup>2</sup> )	/	/
10	<input type="checkbox"/> BABBITT THICKNESS, mm			<input type="checkbox"/> BASE MATERIAL		
11	<input type="checkbox"/> NO. PADS			<input type="checkbox"/> BABBITT THICKNESS, mm		
12	<input type="checkbox"/> LOAD: BETWEEN/ON PAD			<input type="checkbox"/> PIVOT: CENTER/OFFSET, %		
13	<input type="checkbox"/> PIVOT: CENTER/OFFSET, %			<b>LUBRICATION:</b> <input type="checkbox"/> FLOODED <input type="checkbox"/> DIRECTED		
14	<input type="checkbox"/> DAMPER BEARING			<b>THRUST COLLAR:</b> <input type="checkbox"/> INTEGRAL <input type="checkbox"/> REPLACEABLE		
15	<input type="checkbox"/>			BEARING MATERIAL _____		

**16 BEARING TEMPERATURE DEVICES (4.8.5.5)**  SEE ATTACHED API-670 DATA SHEET

18  THERMOCOUPLES

19  SELECTOR SWITCH & IND. BY: \_\_\_\_\_ PURCH \_\_\_\_\_ MFR

20  RESISTANCE TEMPERATURE DETECTORS

21  RESISTANCE MATERIAL \_\_\_\_\_  \_\_\_\_\_ OHMS

22  SELECTOR SWITCH & IND. BY: \_\_\_\_\_ PURCH \_\_\_\_\_ MFR

23  LOCATION-JOURNAL BEARING

24 NUMBER \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

25 OTHER \_\_\_\_\_

26  LOCATION-THRUST BEARING

27 NO. (ACT) \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

28 OTHER \_\_\_\_\_

29 NO. (INACT) \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

30 OTHER \_\_\_\_\_

31  MONITOR SUPPLIED BY (5.4.7.5)

32  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

33  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

34  SCALE RANGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ °C

35  SHTDWN  SET @ \_\_\_\_\_ °C  TIME DLY \_\_\_\_\_ SEC

36 **REMARKS:** \_\_\_\_\_

37 \_\_\_\_\_

38 \_\_\_\_\_

39 \_\_\_\_\_

40 \_\_\_\_\_

41 \_\_\_\_\_

42 \_\_\_\_\_

43 \_\_\_\_\_

44 \_\_\_\_\_

45 \_\_\_\_\_

46 \_\_\_\_\_

47 \_\_\_\_\_

**16 VIBRATION DETECTORS (4.8.5.3)**  SEE ATTACHED API-670 DATA SHEET

**RADIAL VIBRATION DETECTORS:**

18  TYPE \_\_\_\_\_  MODEL \_\_\_\_\_

19  MFR \_\_\_\_\_

20  NO. AT EACH SHAFT BEARING \_\_\_\_\_ TOTAL NO. \_\_\_\_\_

21  OSCILLATOR-DEMODULATOR SUPPLIED BY

22  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

23  MONITOR SUPPLIED BY (5.4.7.8.2)

24  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

25  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

26  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ MICRONS

27  SHUTDOWN  SET @ \_\_\_\_\_ MICRONS  TIME DLY \_\_\_\_\_ SEC

**AXIAL POSITION DETECTOR (4.8.5.3):**

18  SEE ATTACHED API-670 DATA SHEETS

19  TYPE \_\_\_\_\_  MODEL \_\_\_\_\_

20  MFR \_\_\_\_\_  NO. REQUIRED \_\_\_\_\_

21  OSCILLATOR-DEMODULATOR SUPPLIED BY

22  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

23  MONITOR SUPPLIED BY (3.4.7.8.2)

24  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

25  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

26  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ MICRONS

27  SHTDWN  SET @ \_\_\_\_\_ MICRONS  TIME DLY \_\_\_\_\_ SEC

**ACCELERATION TRANSDUCERS**

18  SEE ATTACHED API-670 DATA SHEETS

19  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

20  LOCATION \_\_\_\_\_  NUMBER \_\_\_\_\_

21  MONITOR SUPPLIED BY (3.4.7.8.4)

22  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

23  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

24  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ G

25  SHTDWN  SET @ \_\_\_\_\_ G  TIME DELAY \_\_\_\_\_ SEC

48 **NOTES:** (1) FOR MULTIPLE SHAFT TURBINES, COMPLETE ALL APPLICABLE PORTIONS FOR EACH SHAFT.

49 (2) FOR THREE BEARING SHAFTS, USE A SEPARATE SHEET FOR THE EXTRA BEARING.

50 (3) FOR ROLLING ELEMENT BEARINGS, MODIFY ENTRIES AS REQUIRED. SHOW L-10 BEARING LIFE.



**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 6 OF 10 BY \_\_\_\_\_

**INSTRUMENTS**

1 2 3 4 5 6 7 8 9 10	DESCRIPTION	INSTRUMENT TYPE		INSTRUMENT LOCATION			TRANS-MITTERS FURNISHED BY		CONTROL ROOM RECEIVERS FURN BY	
		INDICATING	RECORDING	LOCAL	LOCAL PANEL	CONTROL ROOM	VENDOR	OTHERS	VENDOR	OTHERS
11	<b>GAS GENERATOR OR SINGLE SHAFT GAS TURBINE</b>									
12	TACHOMETER(S) (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
13	Δ P AIR INLET SYSTEM	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
14	COMPRESSOR DISCHARGE PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
15	FUEL FILTER Δ P	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
16	FUEL SUPPLY PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
17	STARTING GAS SUPPLY PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
18	STARTING GAS EXHAUST PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
19	TEMP COMBUSTOR MEASUREMENT (6 PTS MIN) (4.3.2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
20	TEMP GAS TURB CONTROL PLANE (6 PTS MIN)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
21	INLET AIR TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
22	TEMPERATURE, GG COMPRESSOR DISCHARGE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
23	TEMPERATURE, THRUST BEARING OIL DRAIN	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
24	TEMPERATURE, EACH BEARING SUMP (ROLLING ELEMENT TYPE)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
25	TEMPERATURE, FUEL MANIFOLD	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
26	TEMPERATURE, LUBE OIL RESERVOIR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
27	FIRED HOUR METER	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
28	A) NUMBER STARTS COUNTER	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
29	B) START SEQUENCE TIMER	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
30	LUBE OIL RESERVOIR LEVEL	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
31	LUBE OIL PUMP PRESSURE INDICATORS (NO _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
32	LUBE OIL COOLER OIL INLET TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
33	LUBE OIL COOLER OIL OUTLET TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
34	LUBE OIL COOLER COOLANT INLET TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
35	LUBE OIL COOLER COOLANT OUTLET TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
36	LUBE OIL FILTER Δ P	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
37	LUBE OIL PRESSURE EACH LEVEL (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
38	CONTROL OIL PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
39	SITE FLOW INDICATOR EACH DRAIN (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
40	INLET GUIDE VANE POSITION INDICATOR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
41	EXHAUST DUCT DIFFERENTIAL PRESSURE INDICATOR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
42	ENCLOSURE COOLING AIR EXHAUST TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
43	<b>POWER TURBINE</b>									
44	TACHOMETER(S) (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
45	EXHAUST TEMPRTATURE (2 PTS MIN)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
46	JOURNAL BEARING TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
47	THRUST BEARING TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
48	BEARING DRAIN TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
49	SITE FLOW INDICATOR EACH DRAIN (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
50	LUBE OIL INLET PRESSURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
51	LUBE OIL INLET TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
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**ALARMS AND SHUTDOWNS (5.4.4)**

1 2 3 4 5 6 7 8	DESCRIPTION	APPLIES TO:		(5.4.4.8.5) ANNUNCIATOR POINT IN VENDOR FURNISHED CONTROL PANEL		SENSING DEVICES TO BE FURNISHED BY		INDICATING LIGHT ONLY  (2)
		SINGLE SHAFT OR G.G.	SEP PWR TURB.	(1)		VENDOR	OTHERS	
				ALARM	SHUT- DOWN			
9	RADIAL SHAFT VIBRATION (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input type="checkbox"/>
10	AXIAL THRUST POSITION (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
11	OVERSPEED (1) (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
12	CASING VIBRATION (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
13	HIGH THRUST BEARING TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
14	HIGH RADIAL BEARING TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
15	LOW FUEL SUPPLY PRESSURE	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
16	HIGH FUEL FILTER Δ P	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
17	GAS TURBINE TEMPERATURE SPREAD HIGH	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
18	EXHAUST OVER TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
19	FAILURE OF OVER-TEMPERATURE SHUTDOWN DEVICE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
20	HIGH INLET AIR Δ P EACH FILTER	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
21	COMBUSTOR FLAME-OUT (1)	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
22	CHIP DETECTOR, ANTI FRICTION BEARING	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
23	FAILURE STARTING CLUTCH TO ENGAGE OR DISENGAGE	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
24	LOW OIL PRESSURE (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
25	HIGH LUBE OIL TEMPERATURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
26	LOW LUBE OIL RESERVOIR LEVEL	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
27	HIGH LUBE OIL RESERVOIR LEVEL	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
28	HIGH OIL FILTER Δ P (NO. _____)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
29	LUBE OIL SPARE PUMP OPERATING	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
30	LOW CONTROL OIL PRESSURE	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
31	LOW STARTING GAS PRESSURE	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
32	ANTI-ICING SYSTEM - NOT OPERATING			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
33	LOW D.C. VOLTAGE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
34	EMERGENCY D.C. PUMP OPERATING	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
35	RESERVOIR HEATER "ON"			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
36	IMPLOSION DOOR OPEN			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
37	EXTERNAL PERMISSIVE START SIGNAL			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
38	EXTERNAL SHUTDOWN SIGNAL			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
39	LOSS OF AUXILIARY COOLING AIR			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
40	LAMP TEST PUSH BUTTON			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
41	ENCLOSURE HIGH TEMPERATURE			<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
42	CONTROL SIGNAL FAILURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
43	CONTROL SYSTEM ACTUATOR FAILURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
44	GOVERNOR FAILURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
45	ENCLOSURE VENT FAN FAILURE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
46		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>
47								
48								
49	<b>NOTES:</b>	(1) VENDOR TO ADVISE METHOD OF ANNUNCIATION						
50		(2) VDU MAY USE MESSAGE INDICATOR						

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
S I UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
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**ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER**

**STARTING AND HELPER DRIVERS (5.1)**

- GEARS: SEE SEPARATE API 613 GEAR DATA SHEETS (5.2.1.1)
- DRIVEN EQUIPMENT, SEE SEPARATE API DATA SHEETS
- FIRE PROTECTION EQUIPMENT (5.7.3.1)
  - TYPE  HALON 1301  HALON 1211  CO<sub>2</sub>
  - TYPE OF SENSOR  NUMBER OF DETECTORS
    - ULTRA VIOLET NUMBER \_\_\_\_\_
    - INFRA RED NUMBER \_\_\_\_\_
  - ADDITIONAL LEVELS (5.7.3.2) \_\_\_\_\_

- STARTER ONLY (5.1.1.2)  STARTER/HELPER (5.1.1.3)
- TYPE (5.1.1.1)  MOTOR  STEAM TURBINE
- GAS EXPANDER  IC ENGINE  HYDRAULIC
- GAS TURBINE  STARTER IS CLUTCHED (5.1.1.7)
- HELPER RATING (5.1.2.2) \_\_\_\_\_ kW
- STARTER RATING (5.1.2.1) \_\_\_\_\_ kW
- SHAFT TURNING DEVICE REQUIRED (5.1.3.1)

- MOTOR:
  - TYPE \_\_\_\_\_ RATING \_\_\_\_\_ kW
  - MFR \_\_\_\_\_ MODEL \_\_\_\_\_

- STEAM TURBINE (REFERENCE API DATA SHEETS)
  - MFR \_\_\_\_\_ MODEL \_\_\_\_\_
  - kW \_\_\_\_\_ MAX. STEAM FLOW \_\_\_\_\_ kg/HR
  - TOTAL/START \_\_\_\_\_ kg

- GAS EXPANDER
  - APPLICABLE SPEC. (5.1.1.6) \_\_\_\_\_
  - MFR \_\_\_\_\_ MODEL \_\_\_\_\_
  - kW \_\_\_\_\_ MAX. GAS FLOW \_\_\_\_\_ kg/HR
  - TOTAL/START \_\_\_\_\_ KG

GAS FOR EXPANSION TURBINE:

	MIN	MAX	NORMAL
INLET PRESSURE, kPa	_____	_____	_____
EXHAUST PRESS, kPa	_____	_____	_____
GAS TEMPERATURE, °C INLET	_____	_____	_____
GAS TEMPERATURE, °C EXHAUST	_____	_____	_____
MOLECULAR WEIGHT	_____	_____	_____

- SPEED CONTROL  GOVERNOR  PRESSURE REGULATOR
- YES NO
- INLET CONTROL VALVE FURNISHED \_\_\_\_\_
- STAINLESS STEEL PIPING MANIFOLD \_\_\_\_\_
- CARBON STEEL FLANGES \_\_\_\_\_
- Y-STRAINER W/BREAKOUT FLANGES \_\_\_\_\_
- LOW SPEED CAPABILITY \_\_\_\_\_
- (FOR COMPRESSOR CLEANING)
- RELIEF VALVE PRESSURE SET POINT \_\_\_\_\_ kPag
- CASING MATERIAL \_\_\_\_\_
- SEAL TYPE \_\_\_\_\_

- INTERNAL COMBUSTION ENGINE
  - TYPE  SPARK IGNITED  DIESEL
  - APPLICABLE SPECIFICATION (5.1.1.6) \_\_\_\_\_
  - MANUFACTURER \_\_\_\_\_ MODEL \_\_\_\_\_
  - SPEED \_\_\_\_\_ RPM POWER \_\_\_\_\_ kW

- COMBUSTION GAS TURBINE
  - APPLICABLE SPECIFICATION (5.1.1.6) \_\_\_\_\_
  - MANUFACTURER \_\_\_\_\_ MODEL \_\_\_\_\_
  - SPEED \_\_\_\_\_ RPM POWER \_\_\_\_\_ kW

**MOUNTING PLATES (5.3)**

- TYPE (5.3.1.1)  SOLEPLATE  BASEPLATE
- SHIM PACK THICKNESS \_\_\_\_\_ mm (5.3.1.2.9)

**BASEPLATE (5.3.2)**

- FURNISHED BY \_\_\_\_\_ VENDOR \_\_\_\_\_ (5.3.2.1)
- GAS TURBINE ONLY  EXTENDED FOR \_\_\_\_\_
- SUB-SOLEPLATES REQUIRED (5.3.2.7)  DRIP RIM
- COLUMN MOUNTING (5.3.2.4) (3-POINT)  LEVELING PADS (5.3.2.3)

**ENCLOSURES (5.7.5)**

- ENCLOSURE REQUIRED
- REQUIREMENTS (5.7.5.1):**
  - ACOUSTICAL
  - WEATHERPROOF
  - SAFETY
  - FIREPROTECTION
  - ADDITIONAL VENTILATION (5.7.5.6.3)

**COUPLINGS AND GUARDS (5.2.2)**

- SEE ATTACHED API-671 DATA SHEETS
- MANUFACTURER \_\_\_\_\_  TYPE \_\_\_\_\_
- MODEL \_\_\_\_\_  GUARD SUPPLIED BY \_\_\_\_\_
- MAXIMUM OUTSIDE DIAMETER \_\_\_\_\_ mm
- HUB WEIGHT \_\_\_\_\_ kg
- SPACER LENGTH \_\_\_\_\_ mm  SPACER WEIGHT \_\_\_\_\_ kg
- IDLING ADAPTER REQUIRED  SOLO PLATE REQUIRED
- GUARD SUPPLIED BY \_\_\_\_\_
- TYPE:  FULLY ENCLOSED  SEMI-OPEN  OTHER \_\_\_\_\_
- LUBRICATING REQUIREMENTS:
  - NON-LUBE  GREASE  CONT. OIL LUBE
  - QUANTITY PER HUB \_\_\_\_\_ kg or m<sup>3</sup>/HR

**REMARKS:** \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

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**ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER**

**INLET SYSTEM**

**EXHAUST SYSTEM**

- 3  AIR FILTER (5.5.4.1)
- 4  INERTIAL TYPE SEPARATOR  MEDIA FILTERS
- 5  PAD TYPE PREFILTERS  COMBINATION
- 6  SELF CLEANING (PULSE TYPE)
- 7  SINGLE STAGE WITH PROVISION FOR
- 8 FUTURE EXTRA STAGES  YES  NO
- 9  NORMAL DUST LOADING \_\_\_\_\_ kg/Nm<sup>3</sup>/HR
- 10  WIND DESIGN VELOCITY \_\_\_\_\_ km/HR
- 11  SNOW LOAD \_\_\_\_\_ kg/m<sup>2</sup>
- 12  SEISMIC ZONE \_\_\_\_\_
- 13 LOCATION:  GROUND LEVEL  ELEVATED (5.5.4.6)
- 14  FILTRATION EFFICIENCY \_\_\_\_\_ % (5.5.4.3)
- 15  MAINTENANCE INTERVAL \_\_\_\_\_ MONTHS
- 16  CLEANING FREQUENCY \_\_\_\_\_ DAYS
- 17  IMPLOSION DOOR (5.5.4.5)
- 18  EVAPORATIVE COOLER (5.6.1.1)  ANTI-ICING (5.5.3.10)
- 19  LIQUID TO AIR EXCHANGER (5.6.2.2)
- 20  WALKWAY, LADDERS, HANDRAILS REQUIRED (5.6.1.5)
- 21  COMPRESSOR CLEANING SYSTEM, TYPE \_\_\_\_\_ (5.5.3.9)
- 22  SILENCER PLATE ELEMENT MAT'L (5.5.5.1.4) \_\_\_\_\_
- 23  FILTER MFR. \_\_\_\_\_ MODEL \_\_\_\_\_
- 24 @ 110% RATED AIR FLOW ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 25 CLEAN \_\_\_\_\_ mm H<sub>2</sub>O ALARM \_\_\_\_\_ mm H<sub>2</sub>O
- 26  COOLER MFR. \_\_\_\_\_ MODEL \_\_\_\_\_ ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 27  EXCHANGER MFR (5.6.2.3) \_\_\_\_\_
- 28 MODEL \_\_\_\_\_ ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 29  DUCTING GAUGE / MATERIAL \_\_\_\_\_ / \_\_\_\_\_
- 30  EXPANSION JOINT MFR \_\_\_\_\_ TYPE \_\_\_\_\_
- 31  SILENCER MFR \_\_\_\_\_ ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 32  MANOMETER MFR \_\_\_\_\_ MODEL \_\_\_\_\_
- 33 RANGE \_\_\_\_\_ mm H<sub>2</sub>O
- 34  SYSTEM SITE RATED PRESSURE DROP \_\_\_\_\_ mm H<sub>2</sub>O
- 35 @ 110% RATED AIR FLOW
- 36 **REMARKS:** \_\_\_\_\_
- 37 \_\_\_\_\_
- 38 \_\_\_\_\_
- 39 \_\_\_\_\_
- 40 \_\_\_\_\_
- 41 \_\_\_\_\_
- 42 \_\_\_\_\_
- 43 \_\_\_\_\_

- 3  EXTENT OF FURNISHED INSULATION (SEE SKETCH) (5.7.1.2)
- 4  (RELIEF) (DIVERSION) VALVE (5.5.6.8)
- 5  EXHAUST HEAT RECOVERY SYSTEM (5.5.3.1)
- 6  EMISSION CONTROL SYSTEM (5.5.3.1)
- 7  EXHAUST SILENCER PLATE ELEMENT MATERIAL (5.5.5.2.3) \_\_\_\_\_
- 8 \_\_\_\_\_
- 9  EMISSIONS SAMPLING SYSTEM (5.5.6.10)
- 10  EXPANSION JOINT MFR \_\_\_\_\_ TYPE \_\_\_\_\_
- 11  DUCTING GAUGE/MATERIAL \_\_\_\_\_ / \_\_\_\_\_
- 12  SILENCER MFR \_\_\_\_\_ ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 13  HEAT RECOVERY DEVICE \_\_\_\_\_
- 14 MFR \_\_\_\_\_ TYPE \_\_\_\_\_ ΔP \_\_\_\_\_ mm H<sub>2</sub>O
- 15 STEAM GEN: PRESS \_\_\_\_\_ kPag TEMP \_\_\_\_\_ °C
- 16 RATE \_\_\_\_\_ kg/HR
- 17  MANOMETER MFR \_\_\_\_\_ MODEL \_\_\_\_\_ RANGE \_\_\_\_\_ mm H<sub>2</sub>O
- 18  ATMOSPHERIC RELIEF DEVICE (5.5.6.8)
- 19 TYPE \_\_\_\_\_ MFR \_\_\_\_\_ LOCATION \_\_\_\_\_
- 20  SYSTEM SITE RATED PRESSURE DROP \_\_\_\_\_ mm H<sub>2</sub>O

**ATMOSPHERIC EMISSIONS**

- 3  EMISSION SUPPRESSION SYSTEM REQUIRED (5.8.4.1)
- 4  NO<sub>x</sub> REQUIREMENTS (5.5.3.1.1) \_\_\_\_\_
- 5  NO<sub>x</sub> EMITTED \_\_\_\_\_
- 6 **EMISSIONS REDUCTION METHOD (IF REQUIRED)(5.8.4.2)**
- 7  WATER INJECTION (5.8.4.4)  SCR
- 8  STEAM (5.8.4.4)  DRY COMBUSTOR
- 9  OTHER \_\_\_\_\_
- 10  SO<sub>x</sub> REQUIREMENTS \_\_\_\_\_
- 11  SULFUR CONTENT OF FUEL \_\_\_\_\_
- 12  SO<sub>x</sub> EMITTED (BASED ON STATED SULFUR CONTENT) \_\_\_\_\_
- 13 \_\_\_\_\_
- 14  CO REQUIREMENTS \_\_\_\_\_
- 15  CO EMITTED \_\_\_\_\_
- 16  PARTICULATE REQUIREMENTS \_\_\_\_\_
- 17  PARTICULATE EMITTED \_\_\_\_\_
- 18  UNBURNED HC REQUIREMENTS \_\_\_\_\_
- 19  UNBURNED HC EMITTED \_\_\_\_\_
- 20 **APPLICABLE EMISSION CODES OR REGULATIONS**
- 21  EPA - TITLE 40 - CFR  OTHERS \_\_\_\_\_
- 22 \_\_\_\_\_

**SPECIALIZED INSTRUMENTS**

- 45 **TACHOMETERS:** (5.4.7.2.2)
- 46 TYPE  ELECTRICAL  ELECTRONIC
- 47  ANALOG  DIGITAL
- 48  MANUFACTURER \_\_\_\_\_
- 49  OIL FILLED PRESSURE GAUGES (5.4.7.6)
- 50 \_\_\_\_\_

- 45 **SWITCHES:** (5.4.4.8.2)
- 46 CIRCUIT SHALL
- 47  ENERGIZE  DEENERGIZE TO ALARM
- 48  ENERGIZE  DEENERGIZE TO SHUTDOWN
- 49 ENCLOSURES
- 50  EXPLOSION PROOF  WEATHER PROOF

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
SI UNITS**

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**INSPECTION AND TESTING; LUBRICATION, WEIGHTS**

	REQ	WIT- NESSED	OBSER- VED
2 <b>SHOP INSPECTION AND TESTS:</b> (6.1.1)			
3			
4 SHOP INSPECTION (6.1.2)	<input type="radio"/>		
5 CLEANLINESS (6.2.3.3)	<input type="radio"/>		
6 HYDROSTATIC (6.3.2)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
7 MECHANICAL RUN (6.3.3)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
8 <input type="checkbox"/> CONTRACT COUPLING			
9 <input type="checkbox"/> IDLING ADAPTOR(S)			
10 <input type="checkbox"/> CONTRACT PROBES			
11 <input type="checkbox"/> SHOP PROBES			
12 VIBRATION PLOTS(6.3.3.3.4)	<input type="radio"/>		
13 TAPE RECORD VIB DATA (6.3.3.3.6)	<input type="radio"/>		
14 PERFORMANCE TEST (6.3.4.1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15 COMPLETE UNIT TEST (6.3.4.2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16 PACKAGE TEST(6.3.4.2.1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17 LOAD GEAR TEST (6.3.4.3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18 SOUND LEVEL TEST (6.3.4.4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19 AUXILIARY EQUIPMENT (6.3.4.5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20 POST TEST INSPECTION (6.3.4.6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21 HYDRAULIC COUPLING INSP (6.3.4.7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22 GOVERNOR RESPONSE TEST (6.3.4.8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23 SPARE PARTS (6.3.4.9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24 FIRE PROTECTION (6.3.4.10)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25 OTHER (6.3.4.11) _____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26			

**LUBRICATION SYSTEMS (4.9)**

SEE API 614 DATA SHEETS

LUBE OIL VISCOSITY (4.9.8) ISO GRADE \_\_\_\_\_

COMMON TO  GAS GENERATOR/SINGLE SHAFT TURBINE

FREE POWER TURBINE  LOAD GEAR

DRIVEN EQUIPMENT  AUXILIARIES

(COMBINED) (SEPARATE) LUBE/SEAL SYSTEM (4.9.5)

SYSTEM DESIGNED FOR SYNTHETIC LUBRICANT (4.9.2)

**LUBE SPECIFICATION**

COMMON TO  GAS GENERATOR  POWER TURBINE

LOAD GEAR  DRIVEN EQUIPMENT

AUXILIARIES

<input type="checkbox"/> OIL REQUIREMENTS	FLOW m <sup>3</sup> /HR	PRESSURE kPag	HEAT LOAD MJ/HR
GG OR SS TURBINE	_____	_____	_____
DRIVEN EQUIPMENT	_____	_____	_____
GEAR	_____	_____	_____
COUPLINGS	_____	_____	_____
POWER TURBINE	_____	_____	_____
TOTAL	_____	_____	_____

**MOUNTING ARRANGEMENT**

CONSOLE  COLUMN  BASEPLATE

**MATERIALS INSPECTION REQUIREMENTS (6.2.1.3)**

SPECIAL CHARPY TESTING (4.10.5.3)

RADIOGRAPHY REQUIRED FOR \_\_\_\_\_

MAGNETIC PARTICLE REQUIRED FOR \_\_\_\_\_

LIQUID PENETRANT REQUIRED FOR \_\_\_\_\_

ULTRASONIC REQUIRED FOR \_\_\_\_\_

WELD INSPECTION (4.10.4.6.1) \_\_\_\_\_

WELDING HARDNESS TESTING (6.2.3.4)

**WEIGHTS**

	DRY INSTALLED WT. (kg)	SHIPPING WT. (kg)	DIMEN LxWxH (m)
GG OR SS TURBINE	_____	_____	_____
SS TURB. ROTOR	_____	_____	_____
POWER TURBINE	_____	_____	_____
P.T. ROTOR	_____	_____	_____
LUBE SYSTEM	_____	_____	_____
DRIVEN EQUIPMENT	_____	_____	_____
FILTER	_____	_____	_____
INLET SILENCER	_____	_____	_____
EXHAUST SILENCER	_____	_____	_____
DUCTING	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
MAX ERECTION	_____	_____	_____
WEIGHT (kg)	_____	ITEM	_____
MAX MAINTENANCE	_____	_____	_____
WEIGHT (kg)	_____	ITEM	_____

**MISCELLANEOUS:**

VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION (4.1.18)

FINAL ASSEMBLY CLEARANCES (6.2.1.1 e)

COORDINATION MEETING SITE (7.1.3) \_\_\_\_\_

SPEED-TORQUE CURVE (7.2.4-a)

INCREASE POWER FOR STEAM/WATER (7.2.4 b)

EFFECTS OF AMB. COND. ON EXHAUST FLOW (7.2.4 c)

RUN DOWN CURVES (7.2.4 d)

PURCHASER REVIEW OF CAMP./GOODMAN DIAG. (4.5.3.3)

VENDOR WITNESS ALIGNMENT (4.1.18)

TECHNICAL DATA MANUAL (7.3.6.4)

NUMBER OF PROPOSAL COPIES (7.2.1) \_\_\_\_\_

49 \_\_\_\_\_

50 \_\_\_\_\_

**REMARKS:**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

	JOB NO. _____ ITEM NO. _____ PURCHASE ORDER NO. _____ SPECIFICATION NO. _____ REVISION NO. _____ DATE _____ PAGE 1 OF 10 BY _____
<b>COMBUSTION GAS TURBINE (API 616-4TH)</b> <b>DATA SHEET</b> <b>U.S. CUSTOMARY UNITS</b>	

1 **APPLICABLE TO:**     PROPOSAL     PURCHASE     AS BUILT

2 FOR \_\_\_\_\_ UNIT \_\_\_\_\_

3 SITE \_\_\_\_\_ SERIAL NUMBER \_\_\_\_\_

4 SERVICE \_\_\_\_\_ NUMBER REQUIRED \_\_\_\_\_

5     CONTINUOUS     INTERMITTENT     STANDBY    DRIVEN EQUIPMENT \_\_\_\_\_

6 MANUFACTURER \_\_\_\_\_  MODEL \_\_\_\_\_ ISO RATING (3.17) \_\_\_\_\_ (HP, kW) @ \_\_\_\_\_ RPM

7 NOTE: INFORMATION TO BE COMPLETED:     BY PURCHASER     BY MANUFACTURER     BY MFR IF NOT BY PURCHASER

**GENERAL**

9 **CYCLE:**     REGEN     SIMPLE     EXHAUST HEAT RECOVERY TYPE:     SINGLE SHAFT     MULTI SHAFT

10 DRIVEN EQUIPMENT: NORMAL SHAFT, (HP, kW) \_\_\_\_\_ @ \_\_\_\_\_ RPM    RATED SHAFT (HP, kW) \_\_\_\_\_ @ \_\_\_\_\_ RPM

11 OUTPUT SHAFT SPEED RANGE (4.1.5)     MIN \_\_\_\_\_     MAX \_\_\_\_\_ RPM

12  DESIRED MINIMUM SITE POWER \_\_\_\_\_ (HP, kW) \_\_\_\_\_ RPM

13 OPERATION     ATTENDED     UNATTENDED     POTENTIAL MAXIMUM POWER (3.33) \_\_\_\_\_ kW

14 <b>PERFORMANCE</b>	14 <b>LOCATION (4.1.19)</b>																																																																																										
<p>15 <b>GAS TURBINE INCLUDING ALL LOSSES</b></p> <table style="width:100%; border-collapse: collapse;"> <thead> <tr> <th style="width:20%;"></th> <th style="width:15%;">SITE RATED (3.45)</th> <th style="width:15%;">NORMAL DUTY (3.26)</th> <th style="width:15%;">SITE MAX TEMP</th> <th style="width:15%;">SITE MIN TEMP</th> </tr> </thead> <tbody> <tr><td>19 <input type="radio"/> DRY BULB TEMP, °F</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>20 <input type="radio"/> RELATIVE HUMIDITY %</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>21 <input type="radio"/> BAROMETER, PSIA</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>22 <input type="checkbox"/> OUTPUT, (HP, kW) (1)</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>23 <input type="checkbox"/> HEAT RATE, LHV,</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>24        BTU/(HP, kW)-HR</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>25 <input checked="" type="checkbox"/> OUTPUT SHAFT SPEED, RPM</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>26 <input type="checkbox"/> AIR FLOW, LBS/SEC</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>27 <input type="checkbox"/> EXHAUST FLOW, LBS/SEC (1)</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>28 <input type="checkbox"/> FIRING TEMPERATURE, °F</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>29 <input type="checkbox"/> GAS GEN. EXHAUST TEMP., °F</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>30 <input type="checkbox"/> PT EXHAUST TEMP., °F</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>31 <input type="radio"/> CERTIFIED POINT (3.26)</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>32 (1) INCLUDING    <input type="radio"/> STEAM    <input type="radio"/> WATER EFFECTS FOR</td><td></td><td></td><td></td><td></td></tr> <tr><td>33    <input checked="" type="checkbox"/> EMISSION CONTROL    <input checked="" type="checkbox"/> AUGMENTATION (4.1.9)</td><td></td><td></td><td></td><td></td></tr> <tr><td>34 <input type="checkbox"/> STEAM FLOW, LBS/HR</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr><td>35 <input type="checkbox"/> WATER FLOW, GPM</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr> </tbody> </table>		SITE RATED (3.45)	NORMAL DUTY (3.26)	SITE MAX TEMP	SITE MIN TEMP	19 <input type="radio"/> DRY BULB TEMP, °F	_____	_____	_____	_____	20 <input type="radio"/> RELATIVE HUMIDITY %	_____	_____	_____	_____	21 <input type="radio"/> BAROMETER, PSIA	_____	_____	_____	_____	22 <input type="checkbox"/> OUTPUT, (HP, kW) (1)	_____	_____	_____	_____	23 <input type="checkbox"/> HEAT RATE, LHV,	_____	_____	_____	_____	24        BTU/(HP, kW)-HR	_____	_____	_____	_____	25 <input checked="" type="checkbox"/> OUTPUT SHAFT SPEED, RPM	_____	_____	_____	_____	26 <input type="checkbox"/> AIR FLOW, LBS/SEC	_____	_____	_____	_____	27 <input type="checkbox"/> EXHAUST FLOW, LBS/SEC (1)	_____	_____	_____	_____	28 <input type="checkbox"/> FIRING TEMPERATURE, °F	_____	_____	_____	_____	29 <input type="checkbox"/> GAS GEN. 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37 **APPLICABLE SPECIFICATIONS:**

38  API 616 GAS TURBINES FOR THE PETROLEUM, CHEMICAL, & GAS INDUSTRY SERVICES

39 \_\_\_\_\_

40  GOVERNING SPECIFICATION (IF DIFFERENT) \_\_\_\_\_

41 \_\_\_\_\_

42  VENDOR HAVING UNIT RESPONSIBILITY (4.1.2) \_\_\_\_\_

43 \_\_\_\_\_

44 **SHIPMENT: (6.4)**

45  DOMESTIC     EXPORT     EXPORT BOXING REQUIRED

46  OUTDOOR STORAGE MORE THAN 6 MONTHS (6.4.1)

47 SPARE ROTOR ASSEMBLY PACKAGED FOR (6.4.3.10)

48  DOMESTIC     EXPORT    SHIPMENT

49 COMMENTS: \_\_\_\_\_

50 \_\_\_\_\_

**PAINTING:**

MANUFACTURER'S STANDARD

OTHER \_\_\_\_\_

**NOTE:** All Data Sheets References to GG=Gas Generator, SS = Single Shaft, and PT = Power Turbine

**REMARKS:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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\_\_\_\_\_

\_\_\_\_\_

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
U.S. CUSTOMARY UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
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**FUEL SYSTEM (5.8)**

1  
 2 TYPE  GAS (5.8.2)  LIQUID (5.8.3)  DUAL (5.8.1.5.1)  
 3 **DUAL SYSTEM REQMTS** (5.8.1.5.1)  GAS/GAS  GAS/LIQUID  LIQUID/LIQUID  
 4  COMPLETE FUEL RECEIVING SYSTEM (5.8.1.1)  MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER \_\_\_\_\_ SECONDS

**GAS FUELS (5.8.2)**

**LIQUID FUELS (5.8.3)**

COMPOSITION:	M.W.	NORMAL	STARTING	ALT
11 AIR	29	_____	_____	_____
12 OXYGEN	32	_____	_____	_____
13 NITROGEN	38	_____	_____	_____
14 WATER VAPOR	18	_____	_____	_____
15 CARBON MONOXIDE	28	_____	_____	_____
16 CARBON DIOXIDE	44	_____	_____	_____
17 HYDROGEN	2	_____	_____	_____
18 METHANE	16	_____	_____	_____
19 ETHYLENE	26	_____	_____	_____
20 ETHANE	30	_____	_____	_____
21 PROPYLENE	42	_____	_____	_____
22 PROPANE	44	_____	_____	_____
23 I-BUTANE	58	_____	_____	_____
24 A-BUTANE	58	_____	_____	_____
25 I-PENTANE	72	_____	_____	_____
26 A-PENTANE	72	_____	_____	_____
27 HEXANE PLUS	_____	_____	_____	_____
28 _____	_____	_____	_____	_____
29 TOTAL	_____	_____	_____	_____
30 AVG. MOL. WT.	_____	_____	_____	_____
31 CORS AGNTS (5.8.2.3)	PPM	_____	_____	_____
32 CONTMNTS (5.8.2.2.1)	PPM	_____	_____	_____
33 LHV, BTU/SCFM (5.8.2.4)	_____	_____	_____	_____
34 FUEL PRESS.MAX/MIN, PSIG	_____	/ /	/ /	/ /
35 FUEL TEMPERATURE MAX/MIN, °F	_____	/ /	/ /	/ /
36 <input type="checkbox"/> FUEL PRESSURE REQUIRED	_____	_____	_____	_____
37 MAXIMUM/MINIMUM, PSIG	_____	/ /	/ /	/ /
38 COMPRESSION SYS REQD (5.8.1.2.2)	_____	<input type="radio"/> YES	<input type="radio"/> NO	_____
39 HEATER REQD (5.8.2.1)	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO	_____
40 <input type="radio"/> RATE OF CHANGE OF LHV (5.8.2.4)	_____	_____	_____	_____

8 **FUEL GRADE (5.8.3.3)**  
 9 ASTM D1655 \_\_\_\_\_ ASTM  0GT  1GT  
 10 JET  A  A-1  B D2880  2GT  3GT  4GT  
 11  OTHER, INDICATE ANALYSIS BELOW (5.8.3.3 c)  
 12 LIQUID FUEL TREATMENT REQUIRED  YES  NO  
 13 TREATMENT SYSTEM BY  VENDOR  OTHER \_\_\_\_\_  
 14 FUEL TRANSFER EQUIP REQUIRED (5.8.1.4.5)  YES  NO  
 15 HEATER REQUIRED (5.8.1.4.4)  YES  NO  
 16  LIQUID FUEL PRESS REQUIRED, MAX/MIN, kPag \_\_\_\_\_ / \_\_\_\_\_  
 17 **FUEL ANALYSIS DATA (5.8.3.3)** ASTM METHOD MEASURED VALUE  
 18 **PROPERTY**  
 19 VISCOSITY, SSU @ 100°F D-445 \_\_\_\_\_  
 20 DISTILLATION DATA D-86 \_\_\_\_\_  
 21 50% RECOVERY, °F MAX \_\_\_\_\_  
 22 END POINT, °F MAX \_\_\_\_\_  
 23 SULFUR CONTENT %WEIGHT, MAX. (SELECT APPL. METHOD)  
 24 BOMB METHOD D-129 \_\_\_\_\_  
 25 LAMP METHOD D-1266 \_\_\_\_\_  
 26 HIGH-TEMP METHOD D-1552 \_\_\_\_\_  
 27 CARBON RESIDUE (ON 10% BOTTOMS) % WT. MAX. \_\_\_\_\_  
 28 CONRADSON D-189 \_\_\_\_\_  
 29 RAMSBOTTOM D-524 \_\_\_\_\_  
 30 COPPER STRIP CORROSION PLATE D-130 \_\_\_\_\_  
 31 3 HOURS AT 212°F MAXIMUM  
 32 AROMATIC CONTENT D-1319 \_\_\_\_\_  
 33 ASH CONTENT D-482 \_\_\_\_\_  
 34 SPECIFIC GRAVITY, 60°F D-1298 \_\_\_\_\_  
 35 FLASH POINT, °F D-56 \_\_\_\_\_  
 36 POUR POINT, °F D-97 \_\_\_\_\_  
 37 WATER D-95 \_\_\_\_\_  
 38 FILTERABLE DIRT, MG/100ML D-2276 \_\_\_\_\_  
 39 TRACE METALS (ATOMIC ABSORPTION PREFERRED) D-3605  
 40 SODIUM \_\_\_\_\_  
 41 POTASSIUM \_\_\_\_\_  
 42 VANADIUM \_\_\_\_\_  
 43 CALCIUM \_\_\_\_\_  
 44 LEAD \_\_\_\_\_  
 45 OTHER METALS \_\_\_\_\_  
 46 LOWER HEATING VALUE, BTU/LB D-2382 \_\_\_\_\_

42 **REMARKS:** \_\_\_\_\_  
 43 \_\_\_\_\_  
 44 \_\_\_\_\_  
 45 \_\_\_\_\_  
 46 \_\_\_\_\_

**FUEL SYSTEM PIPING**

49  BY PASS AND VENT VALVE (3.7.1.3)  ISOLATION BLOCK VALVES  ANSI FLANGE RATING  
 50  TWIN Y-TYPE STRAINER WITH CONTINUOUS FLOW  NACE MATERIAL STANDARDS (4.10.1.8)  
 51  TRANSFER VALVE (5.8.1.2.4)

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
U.S. CUSTOMARY UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 3 OF 10 BY \_\_\_\_\_

**CONSTRUCTION FEATURES (NOTE 1)**

**MATERIALS OF CONSTRUCTION (4.10)**

- SPEEDS:
- 3 MAX. CONT. \_\_\_\_\_ RPM TRIP \_\_\_\_\_ RPM
- 4  LATERAL CRITICAL SPEEDS (DAMPED)
- 5 FIRST CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE
- 6 SECOND CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE
- 7 THIRD CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE
- 8 FOURTH CRITICAL \_\_\_\_\_ RPM \_\_\_\_\_ MODE
- 9  PROTOTYPE OR MODIFIED ROTOR SUPPORT (4.7.3.5)
- 10  TRAIN LATERAL ANALYSIS REQUIRED (D.1.3)
- 11  TRAIN TORSIONAL ANALYSIS REQUIRED (2.7.4.5)
- 12  TORSIONAL CRITICAL SPEEDS:
- 13 FIRST CRITICAL \_\_\_\_\_ RPM
- 14 SECOND CRITICAL \_\_\_\_\_ RPM
- 15 THIRD CRITICAL \_\_\_\_\_ RPM
- 16 FOURTH CRITICAL \_\_\_\_\_ RPM

COMPRESSOR ROTOR BLADES \_\_\_\_\_

COMPRESSOR STATOR VANES \_\_\_\_\_

SHAFT \_\_\_\_\_ BLADE/VANE COATING \_\_\_\_\_

TURBINE STAGE	NOZZLES	BLADES	WHEELS OR DISCS
1			
2			
3			
4			

COMBUSTORS \_\_\_\_\_

COMPRESSOR CASING \_\_\_\_\_

COMBUSTOR CASING \_\_\_\_\_

TURBINE CASING \_\_\_\_\_

- 17 **VIBRATION:** (4.7.4.5) (7.2.3 o):
- 18  ALLOWABLE TEST LEVEL: SHAFT \_\_\_\_\_ MILS P/P
- 19 \_\_\_\_\_ CASE \_\_\_\_\_ IN/SEC
- 20  ROTATION, VIEWED FROM DRIVE END  CW  CCW

**GAUGE BOARDS AND CONTROL PANELS**

- 21 **AIR COMPRESSOR:**
- 22 STAGES \_\_\_\_\_ MAXIMUM TIP SPEED \_\_\_\_\_ FPS
- 23 TYPE \_\_\_\_\_ PRESSURE RATIO \_\_\_\_\_
- 24 **CASING SPLIT** (2.2.3)  AXIAL  RADIAL
- 25 ROTOR  SOLID  BUILT UP
- 26 **TURBINE:**
- 27 STAGES \_\_\_\_\_ MAX. TIP SPEED \_\_\_\_\_ FPS
- 28 **CASING SPLIT** (4.2.3)  AXIAL  RADIAL
- 29 ROTOR  SOLID  BUILT UP

**GAUGE BOARDS**

LOCATION \_\_\_\_\_

CONTROL CONSOLES (5.4.5.1.1)  ON-SKID  OFF SKID LOCAL

OFF SKID REMOTE

WEATHER PROTECTION REQUIRED  YES  NO

SPECIFICATION \_\_\_\_\_

ANNUNCIATOR REQUIRED (5.4.4.8.5)

VISUAL DISPLAY UNIT (VDU)  KEYBOARD

- 30 **COMBUSTORS:** (4.3.2)
- 31  SINGLE  MULTIPLE, NUMBER \_\_\_\_\_
- 32  GAS  LIQUID  DUAL FUEL
- 33 MAXIMUM ALLOWABLE TEMP. VARIATION \_\_\_\_\_ °F
- 34 APPLICABLE PLANE \_\_\_\_\_
- 35 FUEL NOZZLES PER COMBUSTOR \_\_\_\_\_
- 36  WOBBE INDEX NO REQD (4.3.7)  MAX \_\_\_\_\_ MIN \_\_\_\_\_

**CONTROL SYSTEMS**

- 37 **MAINTENANCE INTERVALS, HOURS**
- 38  HOT GAS PATH INSPECTIONS \_\_\_\_\_
- 39  MAJOR OVERHAULS \_\_\_\_\_
- 40  OTHER \_\_\_\_\_

TYPE (5.4.1.5)

MECH  PNEU  HYDRA  ELECTRIC  ELECTRONIC

MICROPROCESSOR BASED  COMBINED \_\_\_\_\_

SIGNAL SOURCE \_\_\_\_\_

SENSITIVITY \_\_\_\_\_  RANGE \_\_\_\_\_ TO \_\_\_\_\_

TIME OF AC OUTAGE PROTECTION \_\_\_\_\_ MIN (5.4.1.6)

SHUT OFF VALVES FOR SHUT DOWN SENSORS (5.4.4.9)

STARTING SYSTEM (5.4.2.1)

MANUAL  SEMI AUTOMATIC  AUTOMATIC

PURGE (5.4.2.2) \_\_\_\_\_ MINUTES

SEPARATE SHUTDOWN VALVE TEST DURING OPERATION

- 42 **GOVERNOR** (5.4.3)
- 43  MFR'S STD.  OTHER  MAKE \_\_\_\_\_  MODEL \_\_\_\_\_
- 44  CONSTANT SPEED  VARIABLE SPEED
- 45  ISOCHRONOUS  DROOP
- 46 REMOTE SHUTDOWN SIGNAL  ELECTRIC
- 47  PNEUMATIC  HYDRAULIC  NONE
- 48 MANUAL SPEED CHANGER, RPM \_\_\_\_\_ MAX. \_\_\_\_\_ MIN.
- 49  MAINTAIN TURBINE SPEED UPON FAILURE OF CONTROL
- 50  SIGNAL OR ACTUATOR

**NOTE (1)** FOR MULTIPLE SHAFT TURBINES, COMPLETE ALL APPLICABLE PORTIONS FOR EACH SHAFT.

**REMARKS:** \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
U.S. CUSTOMARY UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 4 OF 10 BY \_\_\_\_\_

**CONSTRUCTION FEATURES CONTINUED (NOTE 1)**

**BEARINGS AND BEARING HOUSINGS (4.8)**

1 2 3	RADIAL (NOTES 2 AND 3)		THRUST (NOTE 3)		ACTIVE	INACTIVE
	INLET	EXHAUST				
4	<input type="checkbox"/> TYPE		<input type="checkbox"/> TYPE			
5	<input type="checkbox"/> MANUFACTURER		<input type="checkbox"/> MANUFACTURER			
6	<input type="checkbox"/> LENGTH, IN		<input type="checkbox"/> UNIT LOAD (ULTIMATE), PSI			
7	<input type="checkbox"/> SHAFT DIAMETER, IN		<input type="checkbox"/> UNIT LOAD (SITE RATED), PSI			
8	<input type="checkbox"/> UNIT LOAD (ACT/ALLOW), PSI	/	<input type="checkbox"/> UNIT LOAD (MAX POTEN.), PSI			
9	<input type="checkbox"/> BASE MATERIAL		<input type="checkbox"/> NO. OF PADS/AREA, (IN <sup>2</sup> )		/	/
10	<input type="checkbox"/> BABBITT THICKNESS, IN		<input type="checkbox"/> BASE MATERIAL			
11	<input type="checkbox"/> NO. PADS		<input type="checkbox"/> BABBITT THICKNESS, IN			
12	<input type="checkbox"/> LOAD: BETWEEN/ON PAD		<input type="checkbox"/> PIVOT: CENTER/OFFSET, %			
13	<input type="checkbox"/> PIVOT: CENTER/OFFSET, %		<b>LUBRICATION:</b> <input type="checkbox"/> FLOODED <input type="checkbox"/> DIRECTED			
14	<input type="checkbox"/> DAMPER BEARING		<b>THRUST COLLAR:</b> <input type="checkbox"/> INTEGRAL <input type="checkbox"/> REPLACEABLE			
15	<input type="checkbox"/>		BEARING MATERIAL _____			

16 **BEARING TEMPERATURE DEVICES (4.8.5.5)**  SEE ATTACHED API-670 DATA SHEET

17

18  THERMOCOUPLES

19  SELECTOR SWITCH & IND. BY: \_\_\_\_\_ PURCH \_\_\_\_\_ MFR

20  RESISTANCE TEMPERATURE DETECTORS

21  RESISTANCE MATERIAL \_\_\_\_\_  \_\_\_\_\_ OHMS

22  SELECTOR SWITCH & IND. BY: \_\_\_\_\_ PURCH \_\_\_\_\_ MFR

23  LOCATION-JOURNAL BEARING

24 NUMBER \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

25 OTHER \_\_\_\_\_

26  LOCATION-THRUST BEARING

27 NO. (ACT) \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

28 OTHER \_\_\_\_\_

29 NO. (INACT) \_\_\_\_\_ EA PD \_\_\_\_\_ EVERY OTH PAD \_\_\_\_\_ PER BRG

30 OTHER \_\_\_\_\_

31  MONITOR SUPPLIED BY (5.4.7.5)

32  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

33  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

34  SCALE RANGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ °F

35  SHTDWN  SET @ \_\_\_\_\_ °F  TIME DLY \_\_\_\_\_ SEC

36 **REMARKS:**

37 \_\_\_\_\_

38 \_\_\_\_\_

39 \_\_\_\_\_

40 \_\_\_\_\_

41 \_\_\_\_\_

42 \_\_\_\_\_

43 \_\_\_\_\_

44 \_\_\_\_\_

45 \_\_\_\_\_

46 \_\_\_\_\_

47 \_\_\_\_\_

16 **VIBRATION DETECTORS (4.8.5.3)**  SEE ATTACHED API-670 DATA SHEET

17

18 **RADIAL VIBRATION DETECTORS:**

19  TYPE \_\_\_\_\_  MODEL \_\_\_\_\_

20  MFR \_\_\_\_\_

21  NO. AT EACH SHAFT BEARING \_\_\_\_\_ TOTAL NO. \_\_\_\_\_

22  OSCILLATOR-DEMOMULATOR SUPPLIED BY

23  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

24  MONITOR SUPPLIED BY (5.4.7.8.2)

25  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

26  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

27  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ MILS

28  SHUTDOWN  SET @ \_\_\_\_\_ MILS  TIME DLY \_\_\_\_\_ SEC

29 **AXIAL POSITION DETECTOR (4.8.5.3):**

30  SEE ATTACHED API-670 DATA SHEETS

31  TYPE \_\_\_\_\_  MODEL \_\_\_\_\_

32  MFR \_\_\_\_\_  NO. REQUIRED \_\_\_\_\_

33  OSCILLATOR-DEMOMULATOR SUPPLIED BY

34  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

35  MONITOR SUPPLIED BY (3.4.7.8.2)

36  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

37  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

38  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ MILS

39  SHUTDOWN  SET @ \_\_\_\_\_ MILS  TIME DLY \_\_\_\_\_ SEC

40 **ACCELERATION TRANSDUCERS**

41  SEE ATTACHED API-670 DATA SHEETS

42  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

43  LOCATION \_\_\_\_\_  NUMBER \_\_\_\_\_

44  MONITOR SUPPLIED BY (3.4.7.8.4)

45  LOCATION \_\_\_\_\_ ENCLOSURE \_\_\_\_\_

46  MFR \_\_\_\_\_  MODEL \_\_\_\_\_

47  SCALE RGE \_\_\_\_\_  ALARM SET @ \_\_\_\_\_ G

48  SHUTDOWN  SET @ \_\_\_\_\_ G  TIME DELAY \_\_\_\_\_ SEC

48 **NOTES:** (1) FOR MULTIPLE SHAFT TURBINES, COMPLETE ALL APPLICABLE PORTIONS FOR EACH SHAFT.

49 (2) FOR THREE BEARING SHAFTS, USE A SEPARATE SHEET FOR THE EXTRA BEARING.

50 (3) FOR ROLLING ELEMENT BEARINGS, MODIFY ENTRIES AS REQUIRED. SHOW L-10 BEARING LIFE.



**COMBUSTION GAS TURBINE (API 616-4TH)  
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INSTRUMENTS									
DESCRIPTION	INSTRUMENT TYPE		INSTRUMENT LOCATION			TRANS-MITTERS FURNISHED BY		CONTROL ROOM RECEIVERS FURN BY	
	INDICATING	RECORDING	LOCAL	LOCAL PANEL	CONTROL ROOM	VENDOR	OTHERS	VENDOR	OTHERS
<b>11 GAS GENERATOR OR SINGLE SHAFT GAS TURBINE</b>									
12 TACHOMETER(S) (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
13 Δ P AIR INLET SYSTEM	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
14 COMPRESSOR DISCHARGE PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
15 FUEL FILTER Δ P	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
16 FUEL SUPPLY PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
17 STARTING GAS SUPPLY PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
18 STARTING GAS EXHAUST PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
19 TEMP COMBUSTOR MEASUREMENT (6 PTS MIN) (4.3.2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
20 TEMP GAS TURB CONTROL PLANE (6 PTS MIN)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
21 INLET AIR TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
22 TEMPERATURE, GG COMPRESSOR DISCHARGE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
23 TEMPERATURE, THRUST BEARING OIL DRAIN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
24 TEMPERATURE, EACH BEARING SUMP (ROLLING ELEMENT TYPE)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
25 TEMPERATURE, FUEL MANIFOLD	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
26 TEMPERATURE, LUBE OIL RESERVOIR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
27 FIRED HOUR METER	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
28 A) NUMBER STARTS COUNTER	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
29 B) START SEQUENCE TIMER	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
30 LUBE OIL RESERVOIR LEVEL	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
31 LUBE OIL PUMP PRESSURE INDICATORS (NO _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
32 LUBE OIL COOLER OIL INLET TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
33 LUBE OIL COOLER OIL OUTLET TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
34 LUBE OIL COOLER COOLANT INLET TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
35 LUBE OIL COOLER COOLANT OUTLET TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
36 LUBE OIL FILTER Δ P	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
37 LUBE OIL PRESSURE EACH LEVEL (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
38 CONTROL OIL PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
39 SITE FLOW INDICATOR EACH DRAIN (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
40 INLET GUIDE VANE POSITION INDICATOR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
41 EXHAUST DUCT DIFFERENTIAL PRESSURE INDICATOR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
42 ENCLOSURE COOLING AIR EXHAUST TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
<b>43 POWER TURBINE</b>									
44 TACHOMETER(S) (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
45 EXHAUST TEMPRTATURE (2 PTS MIN)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
46 JOURNAL BEARING TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
47 THRUST BEARING TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
48 BEARING DRAIN TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
49 SITE FLOW INDICATOR EACH DRAIN (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
50 LUBE OIL INLET PRESSURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
51 LUBE OIL INLET TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					

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**ALARMS AND SHUTDOWNS (5.4.4)**

1 2 3 4 5 6 7 8	DESCRIPTION	APPLIES TO:		(5.4.4.8.5) ANNUNCIATOR POINT IN VENDOR FURNISHED CONTROL PANEL		SENSING DEVICES TO BE FURNISHED BY		INDICATING LIGHT ONLY  (2)
		SINGLE SHAFT OR G.G.	SEP PWR TURB.	(1)		VENDOR	OTHERS	
				ALARM	SHUT- DOWN			
9	RADIAL SHAFT VIBRATION (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>
10	AXIAL THRUST POSITION (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	OVERSPEED (1) (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	CASING VIBRATION (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	HIGH THRUST BEARING TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14	HIGH RADIAL BEARING TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15	LOW FUEL SUPPLY PRESSURE	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16	HIGH FUEL FILTER ΔP	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17	GAS TURBINE TEMPERATURE SPREAD HIGH	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	EXHAUST OVER TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19	FAILURE OF OVER-TEMPERATURE SHUTDOWN DEVICE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20	HIGH INLET AIR ΔP EACH FILTER	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21	COMBUSTOR FLAME-OUT (1)	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22	CHIP DETECTOR, ANTI FRICTION BEARING	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23	FAILURE STARTING CLUTCH TO ENGAGE OR DISENGAGE	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24	LOW OIL PRESSURE (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25	HIGH LUBE OIL TEMPERATURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26	LOW LUBE OIL RESERVOIR LEVEL	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27	HIGH LUBE OIL RESERVOIR LEVEL	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28	HIGH OIL FILTER ΔP (NO. _____)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29	LUBE OIL SPARE PUMP OPERATING	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30	LOW CONTROL OIL PRESSURE	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31	LOW STARTING GAS PRESSURE	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32	ANTI-ICING SYSTEM - NOT OPERATING			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33	LOW D.C. VOLTAGE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34	EMERGENCY D.C. PUMP OPERATING	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35	RESERVOIR HEATER "ON"			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36	IMPLOSION DOOR OPEN			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37	EXTERNAL PERMISSIVE START SIGNAL			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38	EXTERNAL SHUTDOWN SIGNAL			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39	LOSS OF AUXILIARY COOLING AIR			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
40	LAMP TEST PUSH BUTTON			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
41	ENCLOSURE HIGH TEMPERATURE			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
42	CONTROL SIGNAL FAILURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43	CONTROL SYSTEM ACTUATOR FAILURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
44	GOVERNOR FAILURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
45	ENCLOSURE VENT FAN FAILURE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
46		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
47								
48								
49	<b>NOTES:</b> (1) VENDOR TO ADVISE METHOD OF ANNUNCIATION							
50	(2) VDU MAY USE MESSAGE INDICATOR							

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**ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER**

**STARTING AND HELPER DRIVERS (5.1)**

- STARTER ONLY (5.1.1.2)       STARTER/HELPER (5.1.1.3)  
 TYPE (5.1.1.1)     MOTOR       STEAM TURBINE  
 GAS EXPANDER       IC ENGINE       HYDRAULIC  
 GAS TURBINE       STARTER IS CLUTCHED (5.1.1.7)  
 HELPER RATING (5.1.2.2) \_\_\_\_\_ HP  
 STARTER RATING (5.1.2.1) \_\_\_\_\_ HP  
 SHAFT TURNING DEVICE REQUIRED (5.1.3.1)

- MOTOR:  
 TYPE \_\_\_\_\_ RATING \_\_\_\_\_ HP  
 MFR \_\_\_\_\_ MODEL \_\_\_\_\_

- STEAM TURBINE (REFERENCE API DATA SHEETS)  
 MFR \_\_\_\_\_ MODEL \_\_\_\_\_  
 HP \_\_\_\_\_ MAX. STEAM FLOW \_\_\_\_\_ LBS/HR  
 TOTAL/START \_\_\_\_\_ LBS

- GAS EXPANDER  
 APPLICABLE SPEC. (5.1.1.6) \_\_\_\_\_  
 MFR \_\_\_\_\_ MODEL \_\_\_\_\_  
 HP \_\_\_\_\_ MAX. GAS FLOW \_\_\_\_\_ LBS/HR  
 TOTAL/START \_\_\_\_\_ LBS

- GAS FOR EXPANSION TURBINE:  

	MIN	MAX	NORMAL
INLET PRESSURE, PSIA	_____	_____	_____
EXHAUST PRESS, PSIA	_____	_____	_____
GAS TEMPERATURE, °F INLET	_____	_____	_____
GAS TEMPERATURE, °F EXHAUST	_____	_____	_____
MOLECULAR WEIGHT	_____	_____	_____

- 29 SPEED CONTROL     GOVERNOR       PRESSURE REGULATOR  
 YES      NO  
 30 INLET CONTROL VALVE FURNISHED \_\_\_\_\_  
 31 STAINLESS STEEL PIPING MANIFOLD \_\_\_\_\_  
 32 CARBON STEEL FLANGES \_\_\_\_\_  
 33 Y-STRAINER W/BREAKOUT FLANGES \_\_\_\_\_  
 34 LOW SPEED CAPABILITY \_\_\_\_\_  
 35 (FOR COMPRESSOR CLEANING) \_\_\_\_\_  
 36 RELIEF VALVE PRESSURE SET POINT \_\_\_\_\_ PSIG  
 37 CASING MATERIAL \_\_\_\_\_  
 38 SEAL TYPE \_\_\_\_\_

- INTERNAL COMBUSTION ENGINE  
 42 TYPE     SPARK IGNITED       DIESEL  
 43 APPLICABLE SPECIFICATION (5.1.1.6) \_\_\_\_\_  
 44 MANUFACTURER \_\_\_\_\_ MODEL \_\_\_\_\_  
 45 SPEED \_\_\_\_\_ RPM      POWER \_\_\_\_\_ HP

- COMBUSTION GAS TURBINE  
 48 APPLICABLE SPECIFICATION (5.1.1.6) \_\_\_\_\_  
 49 MANUFACTURER \_\_\_\_\_ MODEL \_\_\_\_\_  
 50 SPEED \_\_\_\_\_ RPM      POWER \_\_\_\_\_ HP

- GEARS: SEE SEPARATE API 613 GEAR DATA SHEETS (5.2.1.1)  
 DRIVEN EQUIPMENT, SEE SEPARATE API DATA SHEETS  
 FIRE PROTECTION EQUIPMENT (5.7.3.1)  
 TYPE     HALON 1301       HALON 1211       CO<sub>2</sub>  
 TYPE OF SENSOR       NUMBER OF DETECTORS  
 ULTRA VIOLET      NUMBER \_\_\_\_\_  
 INFRA RED      NUMBER \_\_\_\_\_  
 ADDITIONAL LEVELS (5.7.3.2) \_\_\_\_\_

**MOUNTING PLATES (5.3)**

- TYPE (5.3.1.1)     SOLEPLATE       BASEPLATE  
 SHIM PACK THICKNESS \_\_\_\_\_ IN (5.3.1.2.9)

**BASEPLATE (5.3.2)**

- FURNISHED BY \_\_\_\_\_ VENDOR \_\_\_\_\_ (5.3.2.1)  
 GAS TURBINE ONLY       EXTENDED FOR \_\_\_\_\_  
 SUB-SOLEPLATES REQUIRED (5.3.2.7)       DRIP RIM  
 COLUMN MOUNTING (5.3.2.4) (3-POINT)       LEVELING PADS (5.3.2.3)

**ENCLOSURES (5.7.5)**

- ENCLOSURE REQUIRED  
**REQUIREMENTS (5.7.5.1):**  
 ACOUSTICAL  
 WEATHERPROOF  
 SAFETY  
 FIREPROTECTION  
 ADDITIONAL VENTILATION (5.7.5.6.3)

**COUPLINGS AND GUARDS (5.2.2)**

- SEE ATTACHED API-671 DATA SHEETS  
 MANUFACTURER \_\_\_\_\_  TYPE \_\_\_\_\_  
 MODEL \_\_\_\_\_  GUARD SUPPLIED BY \_\_\_\_\_  
 MAXIMUM OUTSIDE DIAMETER \_\_\_\_\_ IN  
 HUB WEIGHT \_\_\_\_\_ LBS  
 SPACER LENGTH \_\_\_\_\_ IN     SPACER WEIGHT \_\_\_\_\_ LBS  
 IDLING ADAPTER REQUIRED       SOLO PLATE REQUIRED  
 GUARD SUPPLIED BY \_\_\_\_\_  
 TYPE:     FULLY ENCLOSED       SEMI-OPEN       OTHER \_\_\_\_\_  
 LUBRICATING REQUIREMENTS:  
 NON-LUBE       GREASE       CONT. OIL LUBE  
 QUANTITY PER HUB \_\_\_\_\_ LBS or GPM

**REMARKS:**  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

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**ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER**

**INLET SYSTEM**

**EXHAUST SYSTEM**

3  AIR FILTER (5.5.4.1)

4  INERTIAL TYPE SEPARATOR  MEDIA FILTERS

5  PAD TYPE PREFILTERS  COMBINATION

6  SELF CLEANING (PULSE TYPE)

7  SINGLE STAGE WITH PROVISION FOR

8 FUTURE EXTRA STAGES  YES  NO

9  NORMAL DUST LOADING \_\_\_\_\_ LBS/SCFM

10  WIND DESIGN VELOCITY \_\_\_\_\_ MPH

11  SNOW LOAD \_\_\_\_\_ LBS/FT<sup>2</sup>

12  SEISMIC ZONE \_\_\_\_\_

13 LOCATION:  GROUND LEVEL  ELEVATED (5.5.4.6)

14  FILTRATION EFFICIENCY \_\_\_\_\_ % (5.5.4.3)

15  MAINTENANCE INTERVAL \_\_\_\_\_ MONTHS

16  CLEANING FREQUENCY \_\_\_\_\_ DAYS

17  IMPLOSION DOOR (5.5.4.5)

18  EVAPORATIVE COOLER (5.6.1.1)  ANTI-ICING (5.5.3.10)

19  LIQUID TO AIR EXCHANGER (5.6.2.2)

20  WALKWAY, LADDERS, HANDRAILS REQUIRED (5.6.1.5)

21  COMPRESSOR CLEANING SYSTEM, TYPE \_\_\_\_\_ (5.5.3.9)

22  SILENCER PLATE ELEMENT MAT'L (5.5.5.1.4)

23  FILTER MFR. \_\_\_\_\_ MODEL \_\_\_\_\_

24 @ 110% RATED AIR FLOW Δ P \_\_\_\_\_ IN H<sub>2</sub>O

25 CLEAN \_\_\_\_\_ IN H<sub>2</sub>O ALARM \_\_\_\_\_ IN H<sub>2</sub>O

26  COOLER MFR. \_\_\_\_\_ MODEL \_\_\_\_\_ Δ P \_\_\_\_\_ IN H<sub>2</sub>O

27  EXCHANGER MFR (5.6.2.3)

28 MODEL \_\_\_\_\_ D P \_\_\_\_\_ IN H<sub>2</sub>O

29  DUCTING GAUGE / MATERIAL \_\_\_\_\_ / \_\_\_\_\_

30  EXPANSION JOINT MFR \_\_\_\_\_ TYPE \_\_\_\_\_

31  SILENCER MFR \_\_\_\_\_ Δ P \_\_\_\_\_ IN H<sub>2</sub>O

32  MANOMETER MFR \_\_\_\_\_ MODEL \_\_\_\_\_

33 RANGE \_\_\_\_\_ IN H<sub>2</sub>O

34  SYSTEM SITE RATED PRESSURE DROP \_\_\_\_\_ IN H<sub>2</sub>O

35 @ 110% RATED AIR FLOW

36 **REMARKS:** \_\_\_\_\_

37 \_\_\_\_\_

38 \_\_\_\_\_

39 \_\_\_\_\_

40 \_\_\_\_\_

41 \_\_\_\_\_

42 \_\_\_\_\_

43 \_\_\_\_\_

EXTENT OF FURNISHED INSULATION (SEE SKETCH) (5.7.1.2)

(RELIEF) (DIVERSION) VALVE (5.5.6.8)

EXHAUST HEAT RECOVERY SYSTEM (5.5.3.1)

EMISSION CONTROL SYSTEM (5.5.3.1)

EXHAUST SILENCER PLATE ELEMENT MATERIAL (5.5.5.2.3) \_\_\_\_\_

EMISSIONS SAMPLING SYSTEM (5.5.6.10)

EXPANSION JOINT MFR \_\_\_\_\_ TYPE \_\_\_\_\_

DUCTING GAUGE/MATERIAL \_\_\_\_\_ / \_\_\_\_\_

SILENCER MFR \_\_\_\_\_ Δ P \_\_\_\_\_ IN H<sub>2</sub>O

HEAT RECOVERY DEVICE

MFR \_\_\_\_\_ TYPE \_\_\_\_\_ Δ P \_\_\_\_\_ IN H<sub>2</sub>O

STEAM GEN: PRESS \_\_\_\_\_ PSIG TEMP \_\_\_\_\_ °F

RATE \_\_\_\_\_ LBS/HR

MANOMETER MFR \_\_\_\_\_ MODEL \_\_\_\_\_ RANGE \_\_\_\_\_ IN H<sub>2</sub>O

ATMOSPHERIC RELIEF DEVICE (5.5.6.8)

TYPE \_\_\_\_\_ MFR \_\_\_\_\_ LOCATION \_\_\_\_\_

SYSTEM SITE RATED PRESSURE DROP \_\_\_\_\_ IN H<sub>2</sub>O

**ATMOSPHERIC EMISSIONS**

EMISSION SUPPRESSION SYSTEM REQUIRED (5.8.4.1)

NO<sub>x</sub> REQUIREMENTS (5.5.3.1.1) \_\_\_\_\_

NO<sub>x</sub> EMITTED \_\_\_\_\_

**EMISSIONS REDUCTION METHOD (IF REQUIRED)(5.8.4.2)**

WATER INJECTION (5.8.4.4)  SCR

STEAM (5.8.4.4)  DRY COMBUSTOR

OTHER \_\_\_\_\_

SO<sub>x</sub> REQUIREMENTS \_\_\_\_\_

SULFUR CONTENT OF FUEL \_\_\_\_\_

SO<sub>x</sub> EMITTED (BASED ON STATED SULFUR CONTENT) \_\_\_\_\_

CO REQUIREMENTS \_\_\_\_\_

CO EMITTED \_\_\_\_\_

PARTICULATE REQUIREMENTS \_\_\_\_\_

PARTICULATE EMITTED \_\_\_\_\_

UNBURNED HC REQUIREMENTS \_\_\_\_\_

UNBURNED HC EMITTED \_\_\_\_\_

**APPLICABLE EMISSION CODES OR REGULATIONS**

EPA - TITLE 40 - CFR  OTHERS \_\_\_\_\_

**SPECIALIZED INSTRUMENTS**

45 **TACHOMETERS:** (5.4.7.2.2)

46 TYPE  ELECTRICAL  ELECTRONIC

47  ANALOG  DIGITAL

48  MANUFACTURER \_\_\_\_\_

49  OIL FILLED PRESSURE GAUGES (5.4.7.6)

50 **SWITCHES:** (5.4.4.8.2)

CIRCUIT SHALL

ENERGIZE  DEENERGIZE TO ALARM

ENERGIZE  DEENERGIZE TO SHUTDOWN

ENCLOSURES

EXPLOSION PROOF  WEATHER PROOF

**COMBUSTION GAS TURBINE (API 616-4TH)  
DATA SHEET  
U.S. CUSTOMARY UNITS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
 REVISION \_\_\_\_\_ DATE \_\_\_\_\_  
 PAGE 10 OF 10 BY \_\_\_\_\_

**INSPECTION AND TESTING; LUBRICATION, WEIGHTS**

	REQ	WIT- NESSED	OBSER- VED
2 SHOP INSPECTION AND TESTS: (6.1.1)			
4 SHOP INSPECTION (6.1.2)	<input type="radio"/>		
5 CLEANLINESS (6.2.3.3)	<input type="radio"/>		
6 HYDROSTATIC (6.3.2)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
7 MECHANICAL RUN (6.3.3)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
8 <input type="checkbox"/> CONTRACT COUPLING <input type="checkbox"/> IDLING ADAPTOR(S)			
10 <input type="checkbox"/> CONTRACT PROBES <input type="checkbox"/> SHOP PROBES			
12 VIBRATION PLOTS(6.3.3.4)	<input type="radio"/>		
13 TAPE RECORD VIB DATA (6.3.3.6)	<input type="radio"/>		
14 PERFORMANCE TEST (6.3.4.1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15 COMPLETE UNIT TEST (6.3.4.2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16 PACKAGE TEST(6.3.4.2.1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17 LOAD GEAR TEST (6.3.4.3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18 SOUND LEVEL TEST (6.3.4.4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19 AUXILIARY EQUIPMENT (6.3.4.5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20 POST TEST INSPECTION (6.3.4.6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21 HYDRAULIC COUPLING INSP (6.3.4.7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22 GOVERNOR RESPONSE TEST (6.3.4.8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23 SPARE PARTS (6.3.4.9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24 FIRE PROTECTION (6.3.4.10)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25 OTHER (6.3.4.11) _____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

27 **MATERIALS INSPECTION REQUIREMENTS (6.2.1.3)**

28  SPECIAL CHARPY TESTING (4.10.5.3)

29  RADIOGRAPHY REQUIRED FOR \_\_\_\_\_

30  MAGNETIC PARTICLE REQUIRED FOR \_\_\_\_\_

31  LIQUID PENETRANT REQUIRED FOR \_\_\_\_\_

32  ULTRASONIC REQUIRED FOR \_\_\_\_\_

33  WELD INSPECTION (4.10.4.6.1) \_\_\_\_\_

34  WELDING HARDNESS TESTING (6.2.3.4) \_\_\_\_\_

36 **MISCELLANEOUS:**

37  VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION (4.1.18)

38 \_\_\_\_\_

39  FINAL ASSEMBLY CLEARANCES (6.2.1.1 e)

40  COORDINATION MEETING SITE (7.1.3) \_\_\_\_\_

41  SPEED-TORQUE CURVE (7.2.4-a)

42  INCREASE POWER FOR STEAM/WATER (7.2.4 b)

43  EFFECTS OF AMB. COND. ON EXHAUST FLOW (7.2.4 c)

44  RUN DOWN CURVES (7.2.4 d)

45  PURCHASER REVIEW OF CAMP./GOODMAN DIAG. (4.5.3.3)

46  VENDOR WITNESS ALIGNMENT (4.1.18)

47  TECHNICAL DATA MANUAL (7.3.6.4)

48  NUMBER OF PROPOSAL COPIES (7.2.1) \_\_\_\_\_

49 \_\_\_\_\_

50 \_\_\_\_\_

**LUBRICATION SYSTEMS (4.9)**

SEE API 614 DATA SHEETS

LUBE OIL VISCOSITY (4.9.8) ISO GRADE \_\_\_\_\_

COMMON TO  GAS GENERATOR/SINGLE SHAFT TURBINE

FREE POWER TURBINE       LOAD GEAR

DRIVEN EQUIPMENT       AUXILIARIES

(COMBINED) (SEPARATE) LUBE/SEAL SYSTEM (4.9.5)

SYSTEM DESIGNED FOR SYNTHETIC LUBRICANT (4.9.2)

**LUBE SPECIFICATION**

COMMON TO  GAS GENERATOR       POWER TURBINE

LOAD GEAR       DRIVEN EQUIPMENT

AUXILIARIES

<input type="checkbox"/> OIL REQUIREMENTS	FLOW GPM	PRESSURE PSIG	HEAT LOAD BTU/HR
GG OR SS TURBINE	_____	_____	_____
DRIVEN EQUIPMENT	_____	_____	_____
GEAR	_____	_____	_____
COUPLINGS	_____	_____	_____
POWER TURBINE	_____	_____	_____
TOTAL	_____	_____	_____

**MOUNTING ARRANGEMENT**

CONSOLE       COLUMN       BASEPLATE

**WEIGHTS**

	DRY INSTALLED WT. (LBS)	SHIPPING WT. (LBS)	DIMEN LxWxH (FT)
GG OR SS TURBINE	_____	_____	_____
SS TURB. ROTOR	_____	_____	_____
POWER TURBINE	_____	_____	_____
P.T. ROTOR	_____	_____	_____
LUBE SYSTEM	_____	_____	_____
DRIVEN EQUIPMENT	_____	_____	_____
FILTER	_____	_____	_____
INLET SILENCER	_____	_____	_____
EXHAUST SILENCER	_____	_____	_____
DUCTING	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
MAX ERECTION	_____	_____	_____
WEIGHT (LBS)	_____	ITEM	_____
MAX MAINTENANCE	_____	_____	_____
WEIGHT (LBS)	_____	ITEM	_____

**REMARKS:**

\_\_\_\_\_

\_\_\_\_\_

**APPENDIX B—GAS TURBINE VENDOR DRAWING  
AND DATA REQUIREMENTS**

.....

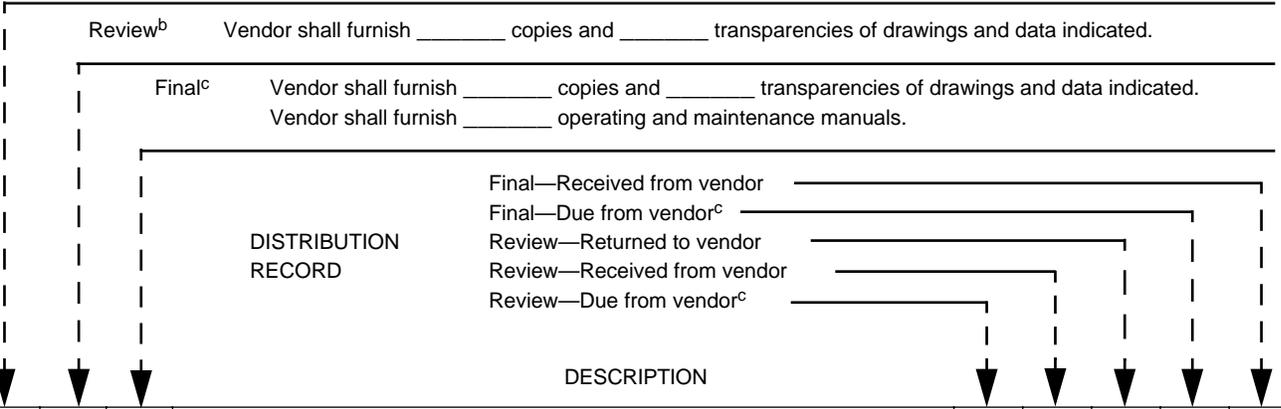
**GAS TURBINE  
VENDOR DRAWING AND  
DATA REQUIREMENTS**

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

FOR \_\_\_\_\_  
 SITE \_\_\_\_\_  
 SERVICE \_\_\_\_\_

REVISION \_\_\_\_\_  
 UNIT \_\_\_\_\_  
 NO. REQUIRED \_\_\_\_\_

Proposal<sup>a</sup> Bidder shall furnish \_\_\_\_\_ copies of data for all items indicated by an X.



			1. Certified dimensional outline drawing and list of connections					
			2. Cross-sectional drawing and bill of materials					
			3. Rotor assembly drawings and bills of materials					
			4. Thrust-bearing assembly drawing and bill of materials					
			5. Journal-bearing assembly drawings and bills of materials					
			6. Shaft-coupling assembly drawings and bills of materials					
			7. Bleed-air/cooling-air sealing and leak-off schematics and bills of materials					
			8. Fuel-system schematics and bills of materials					
			9. Fuel-system component assembly drawings and lists of connections					
			10. Lube-oil/control-oil schematics and bills of materials					
			11. Lube-oil-system assembly and arrangement drawings					
			12. Electrical and instrumentation schematics and bills of materials					
			13. Electrical and instrumentation arrangement drawings and lists of connections					
			14. Governor, control, and trip system data					
			15. Injection-system schematic and bill of materials (optional)					
			16. Injection-system arrangement drawing (optional)					
			17. Tabulation of utility requirements					
			18. Curves showing certified shaft speed versus power at site rated conditions (see Figures 2, 3, or 4)					
			19. Curve showing ambient temperature versus rated power output					
			20. Curve showing output-power shaft speed versus torque					
			21. Curves showing incremental power output vs. water- or steam-system injection rate					
			22. Heat-rate correction factors					
			23. Thrust-bearing performance data					
			24. Blading vibration analysis data					
			25. Lateral critical analysis report					
			26. Torsional critical analysis report					
			27. Transient torsional analysis report					
			28. Allowable flange loadings					
			29. Coupling alignment diagram					
			30. Welding procedures					

<sup>a</sup>Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.  
<sup>b</sup>Purchaser will indicate in this column the desired time frame for submission of materials using the nomenclature given at the end of this form.  
<sup>c</sup>Bidder shall complete these two columns to reflect his actual distribution schedule and shall include this form with his proposal.

**GAS TURBINE  
VENDOR DRAWING AND  
DATA REQUIREMENTS**

JOB NO. \_\_\_\_\_ ITEM NO. \_\_\_\_\_  
PAGE 2 OF 2 BY \_\_\_\_\_  
DATE \_\_\_\_\_ REV NO. \_\_\_\_\_

Proposal<sup>a</sup> Bidder shall furnish \_\_\_\_\_ copies of data for all items indicated by an X.

Review<sup>b</sup> Vendor shall furnish \_\_\_\_\_ copies and \_\_\_\_\_ transparencies of drawings and data indicated.

Final<sup>c</sup> Vendor shall furnish \_\_\_\_\_ copies and \_\_\_\_\_ transparencies of drawings and data indicated.  
Vendor shall furnish \_\_\_\_\_ operating and maintenance manuals.

DISTRIBUTION  
RECORD

Final—Received from vendor \_\_\_\_\_  
Final—Due from vendor<sup>c</sup> \_\_\_\_\_  
Review—Returned to vendor \_\_\_\_\_  
Review—Received from vendor \_\_\_\_\_  
Review—Due from vendor<sup>c</sup> \_\_\_\_\_

DESCRIPTION

			31. Certified hydrostatic test logs					
			32. Mechanical running test logs					
			33. Performance test logs					
			34. Nondestructive test procedures					
			35. Procedures for special and optional tests (see 6.3.4)					
			36. Certified mill test reports					
			37. Rotor balancing logs					
			38. Rotor combined mechanical and electrical runout					
			39. As-built data sheets					
			40. As-built dimensions and data					
			41. Installation manual					
			42. Operating and maintenance manuals					
			43. Spare-parts recommendations					
			44. Engineering, fabrication, and delivery schedule (progress reports)					
			45. List of drawings					
			46. Shipping lists					
			47. List of special tools furnished for maintenance					
			48. Technical data manual					
			49. Material Safety Data Sheets					
			50. Preservation, packaging, and shipping procedures					
			51. Bearing babbitt strength versus temperature curves					

<sup>a</sup>Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.

<sup>b</sup>Purchaser will indicate in this column the desired time frame for submission of materials using the nomenclature given at the end of this form.

<sup>c</sup>Bidder shall complete these two columns to reflect his actual distribution schedule and shall include this form with his proposal.

Notes:

- The vendor shall send all drawings and data to \_\_\_\_\_
- All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.

Nomenclature:

- S—number of weeks before shipment.
- F—number of weeks after firm order.
- D—number of weeks after receipt of approved drawings.

Vendor \_\_\_\_\_  
Date \_\_\_\_\_ Vendor Reference \_\_\_\_\_  
Signature \_\_\_\_\_

(Signature acknowledges receipt of all instructions)

## Description

1. Certified dimensional outline drawing and list of connections, including the following:
  - a. Size, rating, and location of all customer connections.
  - b. Approximate overall handling weights.
  - c. Overall dimensions, maintenance clearances, and dismantling clearances.
  - d. Shaft centerline height.
  - e. Dimensions of baseplates (if furnished), complete with diameter, number, and locations of bolt holes and thickness of the metal through which the bolts must pass, and recommended clearance; centers of gravity; and details for foundation design.
  - f. Direction of rotation.
2. Cross-sectional drawing and bill of materials, including the following:
  - a. Journal-bearing clearances and tolerances.
  - b. Axial rotor float for all rotors (compressor, gas generator, power turbine).
  - c. Shaft end and internal labyrinth seal clearances and tolerances.
  - d. Axial position of rotor disks, blades relative to inlet nozzles or vanes, and tolerance allowed.
  - e. Outside diameter of all disks at the blade tip.
3. Rotor assembly drawings and bills of materials, including the following:
  - a. Axial position from the active thrust-collar face to:
    1. Each impeller or rotating disc, inlet side.
    2. Each radial probe.
    3. Each journal-bearing centerline.
    4. Phase-angle notch.
    5. Coupling face or end of shaft.
  - b. Thrust-collar assembly details, including:
    1. Collar-shaft, with tolerance.
    2. Concentricity (or axial runout) tolerance.
    3. Required torque for locknut.
    4. Surface finish requirements for collar faces.
    5. Preheat method and temperature requirements for shrunk-on collar installation.
  - c. Dimensioned shaft ends for coupling mountings.
4. Thrust-bearing assembly drawing and bill of materials.
5. Journal-bearing assembly drawings and bills of materials for all field-maintainable rotors.
6. Shaft-coupling assembly drawings and bills of materials, including the following:
  - a. Hydraulic mounting procedure.
  - b. Shaft end gap and tolerance.
  - c. Coupling guards.
  - d. Thermal growth from a baseline of 60°F (15°C).
  - e. Make, size, and serial number.
  - f. Axial natural frequency over allowable spacer stretch (disc-type couplings).
  - g. Balance tolerance.
  - h. Coupling "pull-up" mounting dimension.
7. Bleed-air/cooling-air sealing and leak-off schematics and bills of materials, including the following:
  - a. Steady-state and transient air and gas flows and pressures.
  - b. Relief- and control-valve settings.
  - c. Utility requirements, including electricity, water, steam, and air.
  - d. Pipe and valve sizes.
  - e. Instrumentation, safety devices, and control schemes.
  - f. List of purchaser connections (if any).
8. Fuel-system schematics, bills of materials, and data, including the following:
  - a. Fuel compressor/pump performance curves.
  - b. Control valves, relief valves, and instrumentation schematics.
  - c. Vacuum pump schematic, performance curves, cross-section, outline drawing, and utility requirements (if pump is furnished).
9. Fuel-system component assembly drawings and lists of connections, including the following:
  - a. Fuel compressors or pumps.
  - b. Control and relief valves and instruments.
  - c. Steam/water injection (if used).

10. Lube-oil/control-oil schematics and bills of materials, including the following:
  - a. Steady-state and transient oil flows and pressures at each use point.
  - b. Control, alarm, and trip settings (pressures and recommended temperatures).
  - c. Supply temperature and heat loads at each use point at maximum load.
  - d. Utility requirements, including electricity, water, and air.
  - e. Pipe and valve sizes.
  - f. Instrumentation, safety devices, and control schemes.
11. Lube-oil-system assembly and arrangement drawings, including size, rating, and location of all customer connections.
12. Electrical and instrumentation schematics and bills of materials for all systems. The schematics shall show all alarm and shutdown limits (set points).
13. Electrical and instrumentation arrangement drawings and lists of connections.
14. Governor, control, and trip system data, including the following:
  - a. Firing sequence and final settings.
  - b. Control and trip settings.
  - c. Control setting instructions.
  - d. Governor cross-section and setting instructions.
15. Injection-system schematic and bill of materials, including steady-state and transient flows and pressures at each use point.
16. Injection-system arrangement, including the size, rating, and location of all customer connections.
17. Tabulation of utility requirements (may be on as-built purchaser data sheets).
18. Curves showing certified shaft speed versus power at site rated conditions with normal fuel (see Figures 2, 3, or 4). After the order, these curves shall also show any limit on the driven load (such as compressor surge and generator output).
19. Curve showing ambient temperature versus rated power output at rated speed with normal fuel over the ambient range specified.
20. Curve showing output-power shaft speed versus torque (include starter if applicable; see 7.3.4).
21. Curves showing incremental power output versus water- or steam-system injection rate (required only if injection is supplied).
22. Heat-rate correction factors for the curves listed in Items 18–20 and 22 at conditions other than site rated as follows:
  - a. Ambient pressure to maximum and minimum values listed on the data sheets in increments agreed upon at the time of the order (usually no significant change).
  - b. Ambient temperature to maximum and minimum values listed on the data sheets in increments agreed upon at the time of the order.
  - c. Power-output shaft speed from 80 to 105 percent in 5-percent increments (two-shaft machines only).
  - d. Exhaust pressure to maximum and minimum values listed on the data sheets in increments agreed upon at the time of the order.
  - e. Injection-system rate changes (fuel only—treat injection liquid as compressed air).
23. Curves showing performance of thrust-bearing embedded temperature elements as a function of load, shaft speeds, and operating oil-supply temperature.
24. Blading vibration analysis data, including the following:
  - a. Tabulation of all potential excitation sources, such as vanes, blades, nozzles, and critical speeds.
  - b. Campbell diagram for each stage.
  - c. Goodman diagram for each stage.
25. Lateral critical speed analysis report, including but not limited to the following:
  - a. Complete description of the method used.
  - b. Graphic display of critical speeds versus operating speeds.
  - c. Graphic display of bearing and support stiffness and its effect on critical speeds.
  - d. Graphic display of rotor response to unbalance (including damping).
  - e. Journal static loads.
  - f. Stiffness and damping coefficients.
  - g. Tilting-pad bearing geometry and configuration, including:
    1. Pad angle (arc) and number of pads.
    2. Pivot offset.
    3. Pad clearance (with journal radius, pad bore radius, and bearing-set bore radius).
    4. Preload.

26. Torsional critical analysis report, including but not limited to the following:
  - a. Complete description of the method used.
  - b. Graphic display of the mass elastic system.
  - c. Tabulation identifying the mass moment and torsional stiffness of each component identified in the mass elastic system.
  - d. Graphic display of exciting forces versus speed and frequency.
  - e. Graphic display of torsional critical speeds and deflections (mode-shape diagram).
  - f. Effects of alternative coupling on analysis.
27. Transient torsional analysis for all units using synchronous starter/helper motors (mandatory) or driving synchronous generators (optional).
28. Allowable flange loadings for all customer connections, including anticipated thermal movements referenced to a defined point.
29. Coupling alignment diagram, including recommended coupling limits during operation. Note all shaft-end position changes and support growth from a reference ambient temperature of 59°F (15°C) or another temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.
30. Welding procedures for fabrication and repair (see 4.10.1.9, 4.10.4, and 6.2.2.1).
31. Certified hydrostatic test logs.
32. Mechanical running test logs, including but not limited to the following:
  - a. Oil flows, pressures, and temperatures.
  - b. Vibration, including an x-y plot of amplitude and phase angle versus revolutions per minute during start up and coast-down.
  - c. Bearing metal temperatures.
  - d. Observed critical speeds (for flexible rotors).
  - e. Exhaust gas temperature.
  - f. When specified, tape recordings of real-time vibration data (see 6.3.3.3.6).
33. Performance test logs and report in accordance with ASME PTC 22, Section 6, as supplemented by ASME PTC 1, Subpart K, Paragraphs 3.30 and 3.31.
34. Nondestructive test procedures and acceptance criteria as itemized on the purchase order data sheets or the Vendor Drawing and Data Requirements form.
35. Procedures for any special or optional tests (see 6.3.4).
36. Certified mill test reports of items as agreed upon in the precommitment or preinspection meetings.
37. Rotor balancing logs, including a residual unbalance report in accordance with Appendix C.
38. Rotor combined mechanical and electrical runout in accordance with 4.7.5.6.
39. As-built data sheets.
40. As-built dimensions (including nominal dimensions with design tolerances) and data for the following listed parts:
  - a. Shaft or sleeve diameters at:
    1. Thrust collar (for separate collars).
    2. Each seal component.
    3. Each wheel (for stacked rotors) or bladed disk.
    4. Each interstage labyrinth.
    5. Each journal bearing.
  - b. Each wheel or disk 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:
    1. Shaft.
    2. Impellers or bladed disks.
    3. Thrust collar.
    4. Blades, vanes, and nozzles.
41. Installation manual describing the following (see 7.2.6.2):
  - a. Storage procedures.
  - b. Foundation plan.
  - c. Grouting details.

- d. Setting equipment, rigging procedures, component weights, and lifting diagrams.
  - e. Coupling alignment diagram (per Item 29 above).
  - f. Piping recommendations, including allowable flange loads.
  - g. Composite outline drawings for the driver/driven-equipment train, including anchor-bolt locations.
  - h. Dismantling clearances.
42. Operating and maintenance manuals describing the following (see 7.3.6.3):
- a. Start up.
  - b. Normal shutdown.
  - c. Emergency shutdown.
  - d. Operating limits (see 4.7.1.3), other operating restrictions, and list of undesirable speeds (see 4.7.1.3).
  - e. Lube-oil recommendations and specifications.
  - f. Routine operational procedures, including recommended inspection schedules and procedures.
  - g. Instructions for:
    - 1. Disassembly and reassembly of rotor in casing.
    - 2. Rotor unstacking and restacking procedures.
    - 3. Disassembly and reassembly of journal bearings (for tilting-pad bearings, the instructions shall include "go/no-go" dimensions with tolerances for three-step plug gauges).
    - 4. Disassembly and reassembly of thrust bearing.
    - 5. Disassembly and reassembly of seals (including maximum and minimum clearances).
    - 6. Disassembly and reassembly of thrust collar.
    - 7. Wheel reblading procedures.
    - 8. Boring procedures and torque values.
  - h. Performance data, including:
    - 1. Curve showing certified shaft speed versus site rated power.
    - 2. Curve showing ambient temperature versus site rated power.
    - 3. Curve showing output-power shaft speed versus torque.
    - 4. Curve showing incremental power output versus water or steam system injection rate (optional).
    - 5. Heat-rate correction factors (optional).
    - 6. Thrust-bearing performance data.
  - i. Vibration analysis data, per Items 24–27 above.
  - j. As-built data, including:
    - 1. As-built data sheets.
    - 2. As-built dimensions or data, including assembly clearances.
    - 3. Hydrostatic test logs, per Item 31 above.
    - 4. Mechanical running test logs, per Item 32 above.
    - 5. Rotor balancing logs, per Item 38 above.
    - 6. Rotor mechanical and electrical runout at each journal, per Item 38 above.
    - 7. Physical and chemical mill certificates for critical components.
    - 8. Test logs of all specified optional tests.
  - k. Drawings and data, including:
    - 1. Certified dimensional outline drawing and list of connections.
    - 2. Cross-sectional drawing and bill of materials.
    - 3. Rotor assembly drawings and bills of materials.
    - 4. Thrust-bearing assembly drawing and bill of materials.
    - 5. Journal-bearing assembly drawings and bills of materials.
    - 6. Seal-component drawing and bill of materials.
    - 7. Lube-oil schematics and bills of materials.
    - 8. Lube-oil arrangement drawing and list of connections.
    - 9. Lube-oil component drawings and data.
    - 10. Electrical and instrumentation schematics and bills of materials.
    - 11. Electrical and instrumentation arrangement drawings and list of connections.
    - 12. Governor and control- and trip-system drawings and data.
    - 13. Trip- and throttle-valve construction drawings.
43. Spare parts list with stocking level recommendations, in accordance with 7.3.5.
44. Progress reports and delivery schedule, including vendor buy-outs and milestones. The reports shall include engineering, purchasing, manufacturing, and testing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule.
45. List of drawings, including latest revision numbers and dates.
46. Shipping list, including all major components that will ship separately.
47. List of special tools furnished for maintenance (see 5.9).

48. Technical data manual, including the following:
- a. As-built purchaser data sheets, per Item 39 above.
  - b. Certified performance curves, per Items 18–22 above.
  - c. Drawings, in accordance with 7.3.2.
  - d. As-built assembly clearances.
  - e. Spare parts list, in accordance with 7.3.5.
  - f. Utility data, per Item 17 above.
  - g. Vibration data, per Item 24 above.
  - h. Reports, per Items 25, 26, 27, 29, 32, 33, 37, and 38 above.

49. Material Safety Data Sheets (OSHA Form 20).

50. Preservation, packaging, and shipping procedures.

51. Bearing babbitt strength versus temperature curves.

Note: Items 8, 12, 13, 14, 26(f), and 42(k.7–k.9) are required only for a turbine manufacturer's scope of supply.

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## APPENDIX C—PROCEDURE FOR DETERMINATION OF RESIDUAL UNBALANCE

### C.1 Scope

This appendix describes the procedure to be used to determine residual unbalance in machine rotors. Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining residual unbalance is to test the rotor with a known amount of unbalance.

### C.2 Definition

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

### C.3 Maximum Allowable Residual Unbalance

**C.3.1** The maximum allowable residual unbalance per plane shall be calculated using the equation in 4.7.4.2.1.

**C.3.2** If the actual static weight load on each journal is not known, assume that the total rotor weight is equally supported by the bearings. For example, a two bearing rotor weighing 2,700 kilograms (6,000 pounds) would be assumed to impose a static weight load of 1,360 kilograms (3,000 pounds) on each journal.

### C.4 Residual Unbalance Check

#### C.4.1 GENERAL

**C.4.1.1** When the balancing machine readings indicate that the rotor has been balanced to within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

**C.4.1.2** To check the residual unbalance, a known trial weight is attached to the rotor sequentially in six (or twelve, if specified by the purchaser) equally spaced radial positions, each at the same radius. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in C.4.2.

#### C.4.2 PROCEDURE

**C.4.2.1** Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual unbalance [that is, if  $U_{max}$  is 1,440 gm-mm (2 oz.-in.), the trial weight should cause 1,440 to 2,880 gm-mm (2 to 4 oz.-in.) of unbalance].

**C.4.2.2** Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (six or twelve) in equal (60 or 30 degree) increments around the rotor. Add the trial weight to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial weight to any one of the marked radial positions.

**C.4.2.3** To verify that an appropriate trial weight has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial weight should be used. If little or no meter reading results, a larger trial weight should be used. Little or no meter reading generally indicates that the rotor was not balanced correctly, the balancing machine is not sensitive enough, or a balancing machine fault exists (i.e., a faulty pickup). Whatever the error, it must be corrected before proceeding with the residual unbalance check.

**C.4.2.4** Locate the weight at each of the equally spaced positions in turn and record the amount of unbalance indicated on the meter for each position. Repeat the initial position as a check. All verification shall be performed using only one sensitivity range on the balance machine.

**C.4.2.5** Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance (see Figures C-1 and C-2). The maximum meter reading occurs when the trial weight is added at the rotor's heavy spot; the minimum reading occurs when the trial weight is opposite the heavy spot. Thus, the plotted readings should form an approximate circle (see Figures C-3 and C-4). An average of the maximum and minimum meter readings represents the effect of the trial weight. The distance of the circle's center from the origin of the polar plot represents the residual unbalance in that plane.

**C.4.2.6** Repeat the steps described in C.4.2.1 through C.4.2.5 for each balance plane. If the specified maximum allowable residual unbalance has been exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made in any balance plane, the residual unbalance check shall be repeated in all planes.

**C.4.2.7** For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

Note: This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

Equipment (Rotor) No.: \_\_\_\_\_

Purchase Order No.: \_\_\_\_\_

Correction Plane (inlet, drive-end, etc.—use sketch): \_\_\_\_\_

Balancing Speed: \_\_\_\_\_ rpm

$N$ —Maximum Allowable Rotor Speed: \_\_\_\_\_ rpm

$W$ —Weight of Journal (closest to this correction plane): \_\_\_\_\_ kg (lbs)

$U_{max}$ —Maximum Allowable Residual Unbalance =  
 $6350 W/N$  (4  $W/N$ )  
 $6350 \times$  \_\_\_\_\_ kg/\_\_\_\_\_ rpm;  $4 \times$  \_\_\_\_\_ lbs/\_\_\_\_\_ rpm \_\_\_\_\_ gm-mm (oz.-in.)

Trial Unbalance ( $2 \times U_{max}$ ): \_\_\_\_\_ gm-mm (oz.-in.)

$R$ —Radius (at which weight will be placed): \_\_\_\_\_ mm (in.)

Trial Unbalance Weight = Trial Unbalance/ $R$   
 \_\_\_\_\_ gm-mm/\_\_\_\_\_ mm/\_\_\_\_\_ oz.-in./\_\_\_\_\_ inches \_\_\_\_\_ g (oz.)

Conversion Information: 1 ounce = 28.350 grams

**Test Data**

**Rotor Sketch**

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1		
2		
3		
4		
5		
6		
7		

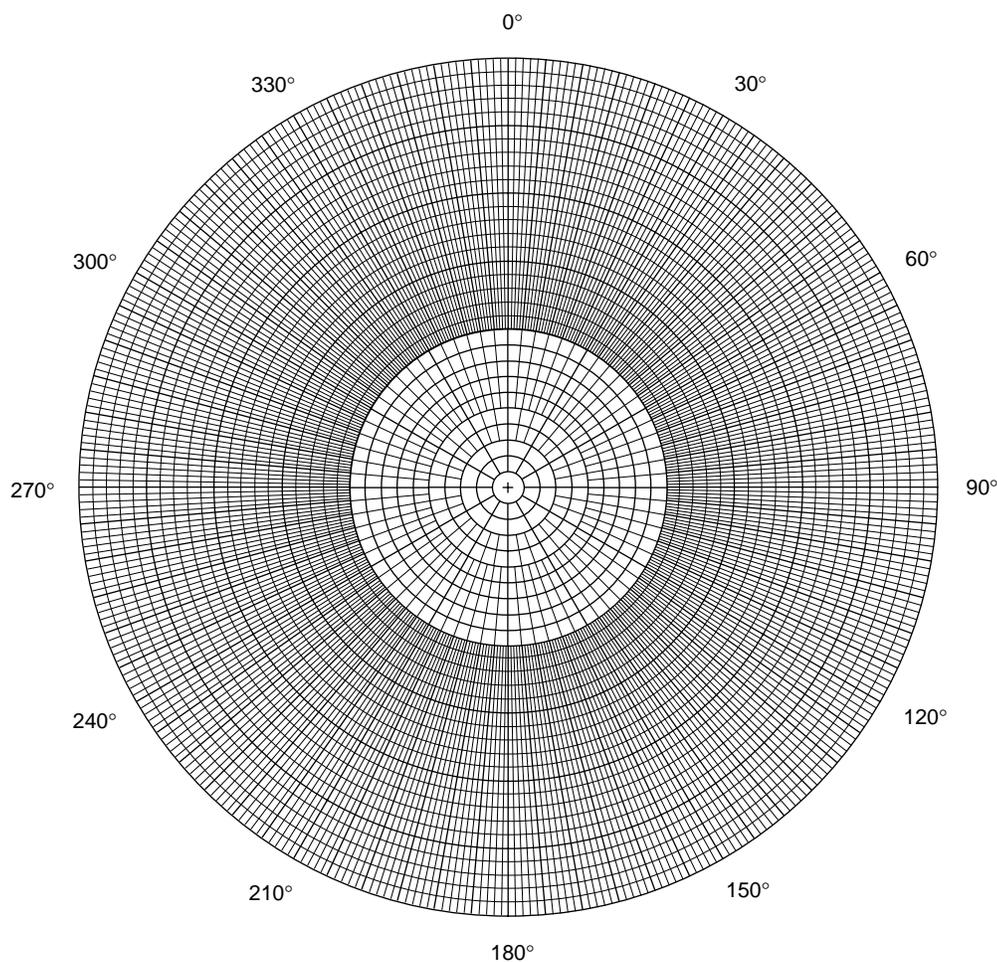
**Test Data—Graphic Analysis**

- Step 1: Plot data on the polar chart (Figure C-2). Scale the chart so the largest and smallest amplitude will fit conveniently.
- Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.
- Step 3: Measure the diameter of the circle in the units of scale chosen in Step 1 and record. \_\_\_\_\_ units
- Step 4: Record the trial unbalance from above. \_\_\_\_\_ gm-mm (oz.-in.)
- Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). \_\_\_\_\_ gm-mm (oz.-in.)
- Step 6: Divide the answer in Step 5 by the answer in Step 3. \_\_\_\_\_ Scale Factor
- You now have a correlation between the units on the polar chart and the gm-in. of actual balance.

**Notes:**

1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
2. The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure C-1—Residual Unbalance Work Sheet



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

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

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

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

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

Correction plane \_\_\_\_\_ for rotor no. \_\_\_\_\_ (has/has not) passed.

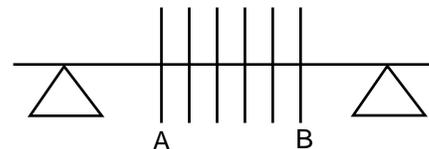
By \_\_\_\_\_ Date \_\_\_\_\_

Figure C-2—Residual Unbalance Work Sheet (continued)

Equipment (Rotor) No.:	<u>C-101</u>
Purchase Order No.:	<u>                    </u>
Correction Plane (inlet, drive-end, etc.—use sketch):	<u>A</u>
Balancing Speed:	<u>800</u> rpm
$N$ —Maximum Allowable Rotor Speed:	<u>10,000</u> rpm
$W$ —Weight of Journal (closest to this correction plane):	<u>908</u> kg (lbs)
$U_{max}$ —Maximum Allowable Residual Unbalance = 6350 $W/N$ (4 $W/N$ ) 6350 × <u>          </u> kg/ <u>          </u> rpm; 4 × <u>908</u> lbs/ <u>10,000</u> rpm	<u>0.36</u> gm-mm (oz.-in.)
Trial Unbalance ( $2 \times U_{max}$ ):	<u>0.72</u> gm-mm (oz.-in.)
$R$ —Radius (at which weight will be placed):	<u>6.875</u> mm (in.)
Trial Unbalance Weight = Trial Unbalance/ $R$ <u>          </u> gm-mm/ <u>          </u> mm/ <u>0.72</u> oz.-in./ <u>6.875</u> inches	<u>0.10</u> g (oz.)
Conversion Information: 1 ounce = 28.350 grams	

**Test Data**

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1	0	14.0
2	60	12.0
3	120	14.0
4	180	23.5
5	240	23.0
6	300	15.5
7	0	14.0

**Rotor Sketch**

C-101

**Test Data—Graphic Analysis**

Step 1: Plot data on the polar chart (Figure C-4). Scale the chart so the largest and smallest amplitude will fit conveniently.

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

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

35 units

Step 4: Record the trial unbalance from above.

0.72 gm-mm (oz.-in.)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).

1.44 gm-mm (oz.-in.)

Step 6: Divide the answer in Step 5 by the answer in Step 3.

0.041 Scale Factor

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

**Notes:**

1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
2. The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

**Figure C-3—Sample Calculations for Residual Unbalance**

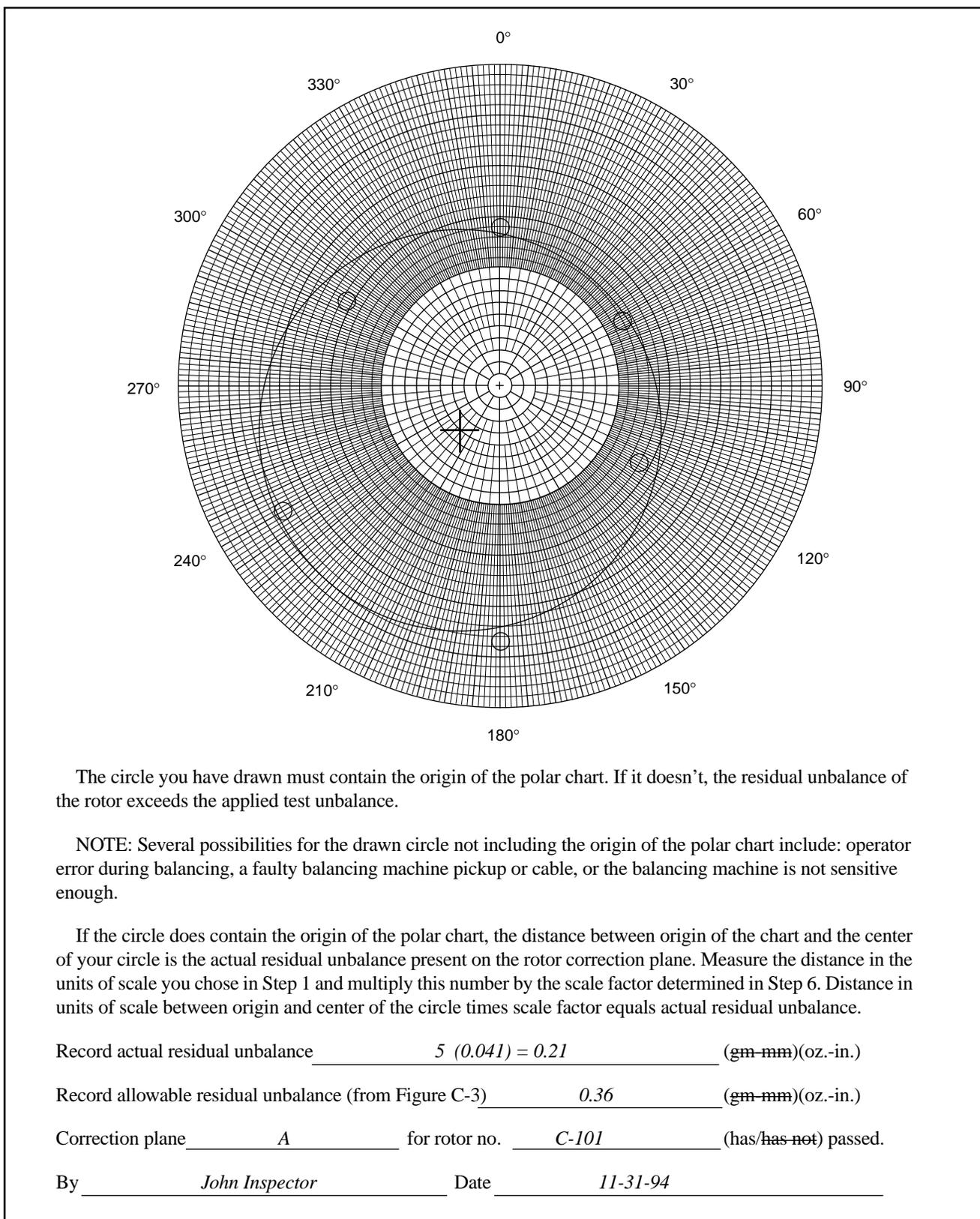


Figure C-4—Sample Calculations for Residual Unbalance (continued)

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## APPENDIX D—LATERAL ROTOR DYNAMIC ANALYSIS FOR USE WITH MODIFIED ROTOR BEARING DESIGNS OR PROTOTYPE GAS TURBINES

### D.1 Lateral Analysis

**D.1.1** The vendor shall provide a damped unbalanced response analysis for the prototype of each gas turbine model, and/or for each modified machine, to assure acceptance amplitudes of vibration at any speed from zero to trip.

**D.1.2** The damped unbalanced response analysis shall include but shall not be limited to the following considerations:

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

b. Bearing lubricant-film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances, and maximum to minimum clearances. For aero derivatives see D.1.2, Item e.

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

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

- **D.1.3** When specified, the effects of other coupled equipment in the train shall be included in the damped unbalanced response analysis (that is, a train lateral analysis shall be performed).

Note: This analysis should be considered for machinery trains with rigid couplings.

**D.1.4** As a minimum, the damped unbalanced response analysis shall include the following. Vendors standard procedures, if equivalent may be used with approval of the purchaser:

Note: Aero-derivative vendors may use their own equivalent methods to produce the same quality of analysis.

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

b. Frequency, phase, and response amplitude data (Bode plots) at the vibration probe locations through the range of

each critical speed, using an arrangement that clearly shows the critical speeds and their associated displacement. The following method is suggested: 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 or the vendor's proven equivalent value:

In SI units,

$$L_v = 25.4 \sqrt{\frac{12,000}{N}}, \quad (D-1)$$

In US Customary units,

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

where

$L_v$  = vibration limit (amplitude of peak to peak unfiltered vibration), in micrometers (mils),

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

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

In SI units,

$$U = 6350 W/N \quad (D-2)$$

In US Customary units,

$$U = 4 W/N$$

where

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

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

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

The unbalance weight or weights shall be placed at the locations that have been analytically determined to affect the particular mode most adversely. For translatory modes, the unbalance shall be based on both journal static weights and shall be applied at the locations of maximum displacement.

For conical modes, each unbalance shall be based on the journal weight and shall be applied at the location of maximum displacement of the mode nearest the journal used for the unbalance calculation, 180 degrees out of phase.

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

d. A verification test of the rotor unbalance. To establish the validity of the analytical model, a verification test of the rotor unbalance is required at the completion of the mechanical running test. Therefore, additional plots based on the actual unbalance to be used during this test shall be provided as follows: For machines that meet the requirements of D.1.4, Item b, and D.1.5, additional Bode plots, as specified in D.1.4, Item b, shall be provided. The location of the test unbalance shall be determined by the vendor. The amount of unbalance shall be sufficient to raise the vibration levels, as measured at the vibration probes, to those specified in D.1.4, Item b. In all cases, the unbalance plots shall include the effects of any test-stand conditions (including the effects of test seals) that may be used during the verification test of the rotor unbalance (see D.2).

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

f. For machines equipped with antifriction-type bearings, the bearing stiffness and damping values used for analysis and the basis for these values. The vendor shall state these values and the basis for them and shall include the assumptions made in calculating the values.

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

**D.1.5** The damped unbalanced response analysis shall indicate that the machine in the unbalanced condition described in D.1.4, Item b, will meet the following acceptance criteria (see Figure D-1). Vendors of aero-derivative gas turbines may use their own standards where analysis and experience clearly

demonstrates that the critical speed does not effect the operation or life of the gas turbine.

- 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 2.5–3.55, 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:

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

- 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:

$$SM = \left( 126 - \frac{6}{AF - 3} \right) - 100 \quad (D-4)$$

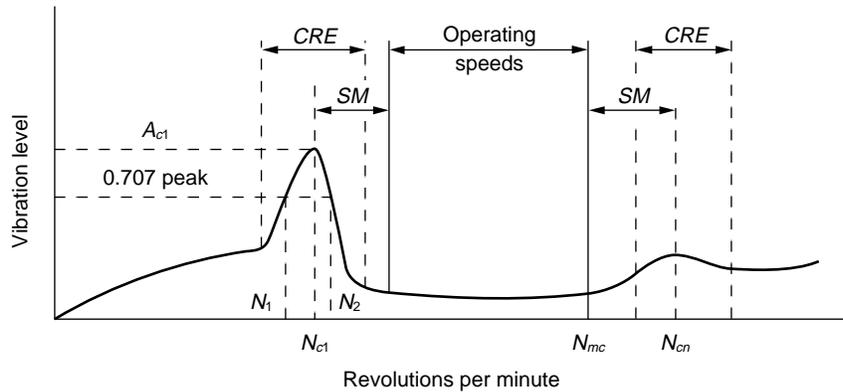
**D.1.6** The calculated unbalanced peak-to-peak rotor amplitudes (see D.1.4, Item b) at any speed from zero to trip shall not exceed 75 percent of the minimum design diametral running clearances throughout the machine (with the exception of floating-ring seal locations). Vendor's standard acceptance criteria may be substituted, if the vendor's design includes the use of abradable or limited contact seals.

**D.1.7** 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 D.1.6.

## D.2 Shop Verification of Unbalanced Response Analysis

**D.2.1** The actual response of the rotor on the test stand to the same unbalanced weight used to develop the results specified in D.1.4 shall be the criterion for determining the validity of the damped unbalanced response analysis. This test shall be performed as part of the mechanical running test of the prototype or modified gas turbine model.

To accomplish this verification, a proper procedure shall be followed, in order to obtain the same unbalance conditions



- $N_{c1}$  = Rotor 1st critical, center frequency, cycles per minute,  
 $N_{cn}$  = Critical speed, nth,  
 $N_{mc}$  = Maximum continuous speed, 105 percent,  
 $N_1$  = Initial (lesser) speed at  $0.707 \times$  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 D-1—Rotor Response Plot

used for the undamped response analysis. The following procedure is suggested:

- a. During the mechanical running test (see 6.3.3), the amplitudes and phase angle of the indicated vibration at the speed nearest the critical or criticals of concern shall be determined.
- b. A trial weight, not more than one-half the amount calculated in, D.1.4, Item b, shall be added to the rotor at the location specified in D.1.4, Item d; 90 degrees away from the phase of the indicated vibration at the speed or speeds closest to the critical or criticals of concern. For overhung rotors, the location of unbalanced weights shall be confined to the coupling end.
- c. The machine shall then be brought up to the operating speed nearest the critical of concern, and the indicated vibration amplitudes and phase shall be measured. The results of this test and the corresponding indicated vibration data from Item a above shall be vectorially added to determine the magnitude and phase location of the final test weight required to produce the required test vibration amplitudes.
- d. The final test weight described in D.2.1, Item c shall be added to the rotor, and the machine shall be brought up to the operating speed nearest the critical of concern. When more than one critical of concern exists, additional test runs shall be performed for each, using the highest speed for the initial test run.

**D.2.2** The parameters to be measured during the test shall be speed and shaft synchronous (1x) vibration amplitudes with corresponding phase. The vibration amplitudes and phase from each pair of x-y vibration probes shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major-axis amplitudes of each response peak shall not exceed the limits specified in D.1.6. (More than one application of the unbalance weight and test run may be required to satisfy these criteria.) For aero-derivative gas turbines case mounted transducers may be substituted for the probes. Acceptance criteria shall be supplied to the purchaser by the vendor.

The gain of the recording instruments used shall be predetermined and preset before the test so that the highest response peak is within 60–100 percent of the recorder's full scale on the test-unit coast-down (deceleration). The major-axis amplitudes at the operating speed nearest the critical or criticals of concern shall not exceed the values predicted in accordance with D.1.4, Item d, before coast-down through the critical of concern.

**D.2.3** The vendor's test acceptance criteria shall be submitted to the purchaser prior to any testing. The test results shall be evaluated against this acceptance criteria and analytical model adjustments made accordingly if required.

**D.2.4** Additional testing is required if, from the test data described above or from the damped, corrected unbalanced response analysis (see D.2.3), it appears that either of the following conditions exists:

- a. Any critical response will fail to meet the separation margin requirements (see D.1.5) or will fall within the operating speed range.
- b. The requirements of D.1.6 have not been met.

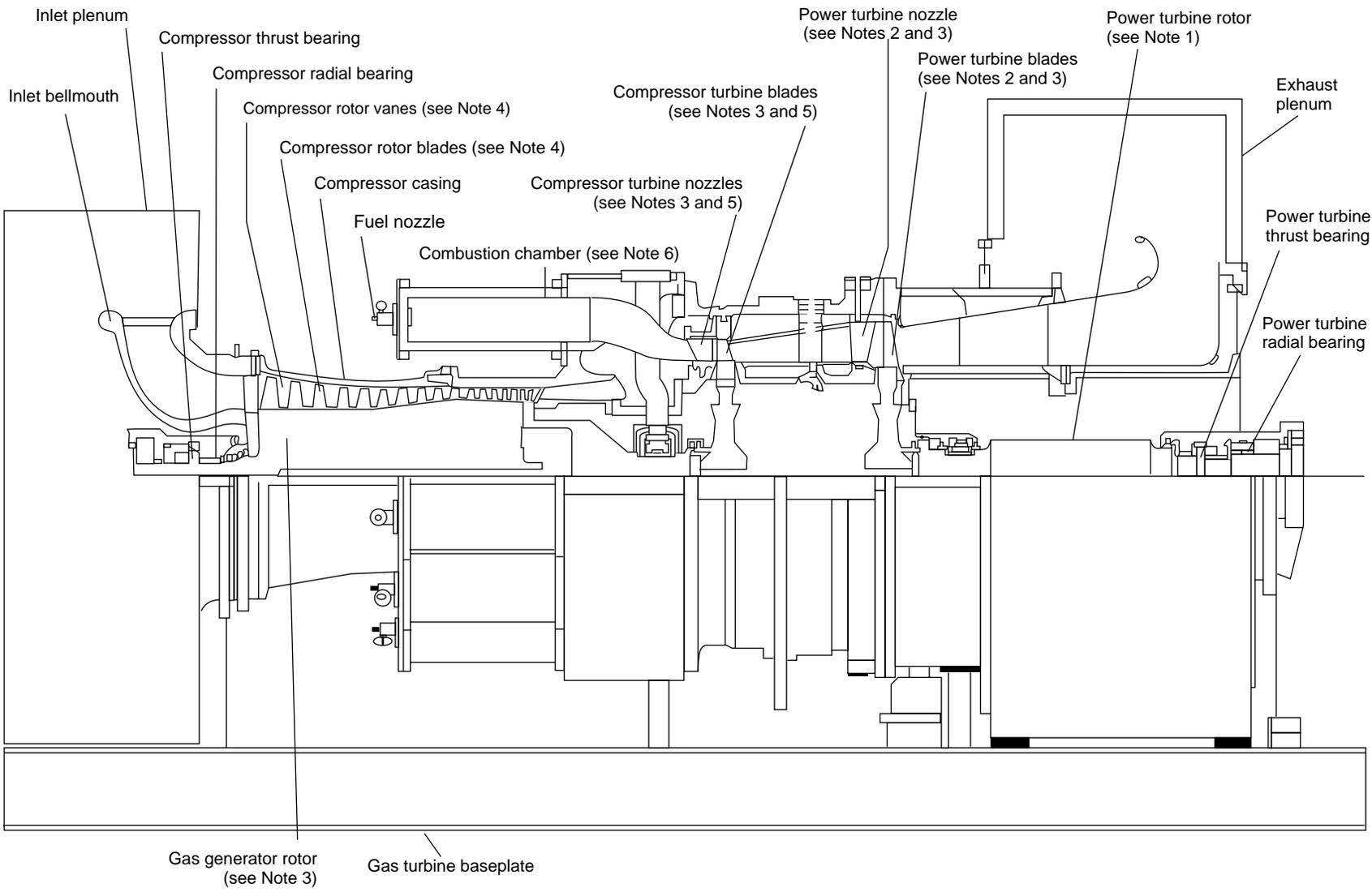
**D.2.5** Rotors requiring additional testing per D.2.4 shall receive additional testing as follows: Unbalance weights shall be placed as described in D.1.4, Item b; this may require disassembly of the machine for placement of the unbalance weights. Unbalance magnitudes shall be achieved by adjusting the indicated unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by Equation D-1 (see D.1.4, Item b) at the maximum continuous speed; however, the unbalance used shall be no less than twice the unbalance limit specified in D.1.4 Item b. The measurements from this test, taken in accordance with D.2.2, shall meet the following criteria:

- a. At no speed outside the operating speed range, including the separation margins, shall the shaft deflections exceed 90 percent of the minimum design running clearances.
- b. At no speed within the operating speed range, including the separation margins, shall the shaft deflections exceed 55 percent of the minimum design running clearances or 150 percent of the allowable vibration limit at the probes (see D.1.4, Item b).

**D.2.6** The internal deflection limits specified in Items a and b above shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in D.1.4, Item c. Actual internal displacements for these tests shall be calculated by multiplying these ratios by the peak readings from the probes. Acceptance will be based on these calculated displacements or inspection of the seals if the machine is opened. Damage to any portion of the machine as a result of this testing shall constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new-part tolerance do not constitute damage.

## APPENDIX E—GAS TURBINE NOMENCLATURE

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- Notes:
- 1. Gas turbine rotors may be single shaft or multiple shaft (shown).
  - 2. Power turbines may be single (shown) or multistage.
  - 3. Turbines may be axial (shown) or radial flow.
  - 4. Compressors may be axial (shown) or radial flow or a combination of both.
  - 5. Compressor turbines may be single (shown) or multistage.
  - 6. Combustion chambers may be cannular (shown), annular, or a single chamber.

Figure E-1—Gas Turbine Nomenclature

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# API Related Publications Order Form

Date: \_\_\_\_\_  
(Month, Day, Year)

API Member  
(Check if Yes)

Invoice To –  Check here if same as "Ship To"

Ship To – (UPS will not deliver to a P.O. Box)

Company: \_\_\_\_\_

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