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Recommended Practice for Packaged Combustion Gas Turbines

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FOREWORD

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This recommended practice is based on the accumulated knowledge and experience of turbine manufacturers, turbine equipment packagers, and users. The objective is to provide a primary procurement document for the design, manufacture, and testing of a complete gas turbine package including the driven equipment. This packaged equipment is intended for use in oil and gas production service.

Historically, API Standard 616 "Gas Turbines for Refinery Service" has been the industry standard for gas turbine equipment procurement. API RP 11 PGT "Recommended Practice for Packaged Combustion Gas Turbines" allows the purchaser the option of requiring compliance with Section 2 of API 616, the turbine manufacturer's standard, or the purchaser's own specification. The purchaser must decide which option best suits the application.

1) API Standard 616 generally addresses industrial, heavy frame type gas turbines. It considers aircraft-derivative designs but not extensively. API Standard 616 was written specifically for refinery services. It should not be used with this packaging specification in its entirety.

2) Specifying a turbine manufacturer's standard design recognizes that most gas turbines are highly standardized machines. This specification provides general requirements and limitations in applying these standard turbine designs.

3) Purchasers may prefer to prepare their own specification to supplement this document.

This packaging recommended practice also accommodates options for driven equipment. The purchaser must evaluate the component specifications available and determine which is most appropriate for the service. This recommended practice is not intended to inhibit technical innovations, energy conservation, or cost reductions.

Note:

This is the first edition of this specification and was approved by Letter Ballet as Practices taken at the 1991 Standardization Conference Circ PS 1952.

SECTION 1
GENERAL

1.1 Scope. This recommended practice is intended to cover the minimum requirements for a complete self-sufficient packaged combustion gas turbine prime mover with or without driven equipment for onshore/offshore oil and gas production services. The package shall be factory assembled to the maximum extent possible as limited by the mode of transportation. All auxiliary equipment required for operating, starting, controlling, and protecting the turbine/driven equipment is included directly or by reference in this recommended practice. Specifically intended to be covered are gas turbine packages capable of continuous service firing gas fuel, liquid fuel, or both.

NOTE: *A bullet (•) in the margin indicates that a decision by the purchaser is required. These decisions should be indicated directly on the data sheets when provisions are made for them; otherwise, they should be stated in the quotation request or in the order.*

1.2 Alternative Designs. The packager may offer alternative designs [5.1.1]. Equivalent metric dimensions, fasteners, and flanges may be substituted as mutually agreed upon by the purchaser and the packager.

1.3 Conflicting Requirements. In case of conflict between this recommended practice and the inquiry or order, the information included in the order shall govern. The packager and purchaser should jointly determine and quickly resolve any conflicts before placement of the order.

1.4 Definition of Terms. The terms used in this recommended practice are defined as follows:

1.4.1 Alarm point is a preset value of a parameter at which an alarm is actuated to warn of a condition requiring corrective action.

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

1.4.3 Critical speed corresponds to resonant frequencies of the system and of the forcing phenomena. If the frequency of any harmonic component of a periodic forcing phenomenon is equal to, or approximates the frequency of any mode of rotor vibration, a condition of resonance may exist; if resonance exists at a finite speed, that speed is called a critical speed.

1.4.4 Use of the word **Design** in any terms 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 manufacturer.

1.4.5 A Filter Stage is 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 media, an inertial separator, a mist eliminator, or a self-cleaning section. Multistage filters are combinations of the various filter stages.

1.4.6 Gas generators are devices in which only that energy required to drive the compressor stages and auxiliaries is extracted from the discharging gas by its turbine stages.

1.4.7 Heat rate is the gas turbine's energy consumption per unit of output work. Heat rate is expressed in British Thermal Units (BTU) per horsepower-hour at the output shaft for mechanical drives or in BTU per kilowatt-hour at the generator terminals for electric generator sets. Both are based on the lower heating value of the fuel.

1.4.8 Inlet cubic feet per minute (ICFM) refers to the flow rate determined at the conditions of pressure, temperature, compressibility, and gas composition, including moisture at the compressor inlet flange. Actual cubic feet per minute (ACFM) may be used to refer to flow at a number of locations and should, therefore, not be used interchangeably with inlet cubic feet per minute.

1.4.9 Local means mounted on, attached to, or adjacent to the package or equipment skids.

1.4.10 Maximum allowable speed (in revolutions per minute) is the highest speed at which the manufacturer's design will permit continuous operation.

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

1.4.12 Maximum allowable working pressure is the maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified temperature [Appendix A].

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

1.4.14 Minimum allowable speed (in revolutions per minute) is the lowest speed at which the manufacturer's design will permit continuous operation.

1.4.15 Normally open and normally closed refer to "on-the-shelf" positions and designate the de-energized positions of devices such as automatically controlled electric switches and valves. It is emphasized that the position of such a device during operation of the equipment is not necessarily the same as the device's "on-the-shelf" position.

1.4.16 Normal operating point is the point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the packager certifies that performance is within the tolerances stated in this practice. This includes power, speed, and heat rate at specified site conditions and fuel composition.

1.4.17 The packager is the vendor having responsibility for coordinating the technical aspects of the equipment, and all auxiliary systems included in the scope of the order [2.2.1, 2.2.2, 2.2.3]. Responsibility for such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, and testing of components is included.

1.4.18 Panel is an enclosure used to mount, display, and protect gages, switches, and other instruments.

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

1.4.20 Power turbine is a mechanical prime mover specifically designed for recovery of energy from hot gases produced by the gas generator.

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

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

1.4.23 Rated cycle temperature at ISO conditions is 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.

1.4.24 Rated firing temperature at ISO conditions is the vendor's stated (calculated) turbine inlet temperature, immediately upstream of the first-stage turbine nozzles, for continuous service at ISO rated power output.

1.4.25 Rated power at ISO conditions is the continuous power developed by the gas turbine when it is operated at rated firing temperature and speed under the following standard operating conditions (ISO 2314).

Inlet temperature	59 F (15 C)
Inlet (total) pressure	14.696 psia (1.0133 bar)
Inlet Relative Humidity	60%
Exhaust pressure	14.696 psia (1.0133 bar)

This power and speed is measured at the output shaft of the gas turbine ahead of any separate gears or driven equipment except in the case of electric generators where power output is measured at the generator terminals. The inlet conditions shall be measured at the gas generator inlet flange and exhaust conditions at the exhaust flange. These measuring points shall be utilized for all power and gas flow measurements. The ISO rating provides only general sizing information and should not be confused with the site rated power.

1.4.26 Rated speed (in revolutions per minute) is the speed of the gas turbine output shaft at which site rated power is developed.

1.4.27 Remote means located away from the package or equipment skids, typically in a control room or data transmission facility.

1.4.28 Site rated conditions are the specified values of the inlet air temperature, inlet air pressure, and exhaust gas 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.

1.4.29 Site rated cycle temperature is the turbine inlet total temperature immediately upstream of the first stage turbine rotor blades, required to meet site rated power.

1.4.30 Site rated firing temperature is the turbine inlet temperature, immediately upstream of the first stage turbine nozzles, required to meet site rated power.

1.4.31 Site rated power is the power developed by the gas turbine at the output shaft when it is operated at site rated firing temperature, rated speed, and rated site conditions, rated fuel composition, and with or without steam or water injection. (External auxiliaries are not included in parasitic losses.)

1.4.32 Shutdown point is a preset value of a parameter requiring automatic or manual shutdown of the system.

1.4.33 Standard cubic feet per minute (SCFM) refers to capacity at a pressure of 14.7 pounds per square inch absolute (1.01 bar) and a temperature of 60°F (15.56°C).

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

1.4.35 Thermal efficiency (η) is the ratio of the energy output at the power turbine shaft to the energy input (based on lower heating value of the fuel) expressed in the same units. (External auxiliaries are not included in parasitic losses.)

$$\eta = \frac{\text{Output BHP} \times 2545}{\text{Input BTU/HR (LHV)}} \quad \text{(Mechanical Drive)}$$

$$\eta = \frac{\text{Output Kw} \times 3412}{\text{Input BTU/HR (LHV)}} \quad \text{(Generator Drive)}$$

1.4.36 Trip speed (in revolutions per minute) is the speed at which the independent emergency overspeed device operates to shut down the gas turbine.

1.5 Referenced Publications.

1.5.1 The purchaser and the packager shall mutually determine the measures that must be taken to comply with any federal, state, or local codes, regulations, ordinances, or rules that are applicable to the equipment (O.S.H.A., UBC, etc.). Purchaser will be responsible for providing applicable state and local codes, regulations, ordinances, and rules.

1.5.2 The current editions of the following standards, codes, and specifications shall, to the extent specified herein, form a part of this recommended practice. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the purchaser and the packager:

AGMA[1]

Std 420 Practice for Helical and Herringbone Gear Speed Reducers and Increasers

Std 421 Practice for High Speed Helical and Herringbone Gear Units

AISC[2] — Manual of Steel Construction

AISI[3] — Standard Type 300 Stainless Steel

— Standard Type 1020 Plain Carbon Steel

ANSI[4]

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

B16.5 Steel Pipe Flanges and Flanged Valves and Fittings

B31.3 Chemical Plant and Petroleum Refinery Piping

C50.10 General Requirements for Synchronous Machines

C50.12 Requirements for Salient-Pole Synchronous Generators

C50.13 Requirements for Cylindrical-Rotor Synchronous Generators

C50.14 Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators

S5.1 Test Code for the Measurement of Sound from Pneumatic Equipment

Y14.2M Line Conventions and Lettering

API[5]

RP-541 Form Wound Squirrel-Cage Induction Motors, 250HP and Larger

RP-546 Form Wound Brushless Synchronous Motors - 500 hp and larger

RP-550 Manual on Installation of Refinery Instruments and Control Systems

Std 610 Centrifugal Pumps for General Refinery Services

Std 611 General Purpose Steam Turbines for Refinery Services

Std 613 Special Purpose Gear Units for Refinery Services

Std 614 Lubrication, Shaft-Sealing, and Control Oil Systems for Special Purpose Applications

Std 616 Gas Turbines for Refinery Services

Std 617 Centrifugal Compressors for General Refinery Services

Std 618 Reciprocating Compressors for General Refinery Services

Std 660 Shell and Tube Heat Exchangers for General Refinery Services

Std 661 Air Cooled Heat Exchangers for General Refinery Services

Std 670 Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems

Std 671 Special Purpose Couplings for Refinery Services

Std 678 Accelerometer-Based Vibration Monitoring System

ASME[6]

Boiler and Pressure Vessel Code:
Section V, Nondestructive Examinations
Section VIII, Unfired Pressure Vessels
Section IX, Welding and Brazing Qualifications

B1.20.1, General Purpose (inch) Pipe Threads
B31.3, Chemical Plant and Petroleum Refinery Piping

Power Test Code:
PTC-1, General Instructions.
PTC-22, Gas Turbine Power Plants.

ASTM[7]

A36 Structural Steel

A53 Zinc-Coated Welded and Seamless Black and Hot-Dipped Steel Pipe

A105 Carbon Steel Forgings for Piping Components

A106 Seamless Carbon Steel Pipe for High-Temperature Service

A120 Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Use

A123 Zinc (Hot Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plated, Bars, and Strip

A153 Zinc Coating (Hot Dipped) on Iron and Steel Hardware

A193 Alloy Steel and Stainless Steel Bolting Materials for High Temperature

A194 Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service

A197 Cupola Malleable Iron

A202 Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon

A269 Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A307 Carbon Steel Externally Threaded Standard Fasteners

A312 Seamless and Welded Austenitic Stainless Steel Pipe

A338 Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine, and other Heavy Duty Service at Temperatures up to 650F (345C)

A358 Electric Fusion Welded Austenitic Cr-Ni Alloy Steels Pipes for High Temperature Service

A500 Cold Formed Welded and Seamless Carbon Steel Structural Tubing on Rounds and Shapes

A515 Pressure Vessel Plates, Carbon Steel, for Intermediate and Higher Temperature Service

A524 Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures

A525 General Requirements for Steel Sheet, Zinc Coated (Galvanized) by the Hot Dip Process

A569 Steel, Carbon (0.15 max), Hot Rolled Sheet and Strip, Commercial Quality

A591 Steel Sheet, Cold Rolled, Electrolytic Zinc Coated

A606 Steel Sheet and Strip, Hot Rolled and Cold Rolled, High Strength, Low Alloy, with Improved Atmospheric, Corrosion Resistance

A662 Specification for Pressure Vessel Plates, Carbon, Manganese for Moderate and Lower Temperature Service.

E94 Guides for Radiographic Testing

E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E142 Method for Controlling Quality of Radiographic Testing

E709 Practice for Magnetic Particle Examination

AWS[8]

D1.1 Structural Welding Code - Steel

IEEE[9]

45 Recommended Practice for Electrical Installation on Shipboards

115 Test Procedures for Synchronous Machines

522 Guide for Testing Turn-to-Turn Insulation on Form-Wound Stator Coils for AC Rotating Electric Machines, 1977 Edition (Reaffirmed 1981)

ISO[10]

ISO-2314 — Gas Turbines - Acceptance Tests

ISO-3448 — Standard Industrial Liquid Lubricants — ISO Viscosity Classification

MIL[11]

Mil-E-5007 Engines, Aircraft, Turbojet, and Turbofan, General Specifications for

Mil-STD-1534 Engines, Aircraft, Gas Turbines Technical Design Requirements

NACE[12]

MR-01 Sulfide Stress Corrosion Cracking Resistant Metallic Material for Oilfield Equipment

NEMA[13]

MG1-20 Motors and Generators (Induction Motors)

MG1-21 Motors and Generators (Synchronous Motors)

MG1-22 Motors and Generators (Synchronous Generators)

SM-23 Steam Turbines for Mechanical Drive Services

NFPA[14]

37 Stationary Combustion Engines and Gas Turbines

70 National Electrical Code
500 Laboratory Classified Locations
501 Class I Locations
502 Class II Locations

72E Automatic Fire Detectors

OSHA[15]

Code of Federal Regulations (CFR) 29 CFR 1910 — Occupational Safety and Health Standards

SAE[16]

TEMA[17] Standards, Codes, and Specification

UBC[18] Uniform Building Code

Reference standards may be obtained from the following organizations.

[1]American Gear Manufacturer's Association, 1901 Fort Myer Dr., Arlington, VA 22209

[2]American Institute of Steel Construction, Inc. 400 North Michigan Avenue, Chicago, IL 60611

[3]American Iron and Steel Institute, 1000 16th Street, N.W., Washington, DC 20036

[4]American National Standards Institute, 1430 Broadway, New York, NY 10018

[5]American Petroleum Institute, 1220 L Street North West, Washington, D.C. 20005

[6]American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

[7]American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

[8]American Welding Society, 550 NW LeJeune Rd., Miami, FL 33135

[9]Institute of Electrical and Electronic Engineers, 345 East 47th Street, New York, NY 10017-2394

[10]International Organization for Standardization. ISO publications are available from ANSI (4)

[11]Department of Defense - obtain from: Commanding Officer, Naval Publications Forms Center, ATTN: NPFC 105, 5801 Tabor Ave., Philadelphia, PA 19120

[12]National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218

[13]National Electrical Manufacturer's Association, 2101L Street, NW, Washington, DC 20037

[14]National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

[15]Occupational Safety and Health Administration, U.S. Department of Labor. The Code of Federal Regulations is available from the U.S. Government Printing Office, Washington, DC 20402

[16]Society of Automotive Engineers, Inc., Aerospace Materials Division, 400 Commonwealth Drive, Warrendale, PA 15096

[17]Tubular Exchanger Manufacturer's Association, 25 North Broadway, Terrytown, NY 10591

[18]International Conference of Building Officials (UBC), 5360 South Workman Mill Road, Whitter, CA 90601.

SECTION 2
BASIC PACKAGE DESIGN

2.1 Site Specific Requirements.

2.1.1 Service Life. The complete package covered by this recommended practice shall be designed and constructed for a minimum service life of 20 years and minimum uninterrupted continuous service interval of 3 years. The hot gas path inspection interval shall be a minimum of 8000 hours. It is recognized that these are design criteria. It is recognized that applications with marginal fuels and/or water or steam injection may require a more frequent inspection interval. It is the purchaser's responsibility to provide the packager pertinent site information. It is the packager's responsibility to identify in his proposal any special equipment and maintenance procedures necessary to achieve the aforesaid life and service intervals.

2.1.2 Unit Responsibility. The packager shall be responsible for complete train performance and the mechanical integrity of the entire package to meet specified performance.

• **2.1.3 Site Rating Condition.** The purchaser will specify the package site specific operating point(s) on the data sheets [Appendix A]. Unless otherwise specified, the gas turbine shall be designed to provide site rated power with no negative tolerance at the heat rate quoted.

• **2.1.4 Starting Requirements.** The purchaser will define any operating requirements which impact start cycle sequence or duration [2.2.9].

• **2.1.5 Transient Requirements.** Operational stability under load transients shall meet the requirement as specified by the purchaser. These requirements should be clearly defined by a relationship of load, speed, and time parameters.

• **2.1.6 Instrumentation/Communication.** Minimum controls requirements are defined by 2.2.15. The purchaser will specify any additional requirements for instrumentation, data acquisition, data transmission, and system interface with total facility.

2.1.7 Maintenance/Inspection. Recommended inspections, normal maintenance, and major overhaul intervals shall be stated in the packager's proposal. The package shall be designed for ease in servicing and to provide adequate clearances necessary to perform all normal maintenance, and changeout of components on the package. Special tools and procedures shall be stated in the packager's proposal. All tool lists, parts list, and maintenance procedures shall be included in the packager's maintenance manual.

2.1.8 Spare Parts.

2.1.8.1 The packager shall consider the specific site conditions and include in his proposal a list of spares needed to complete package commissioning and field acceptance of initial operations. A second list of spares for three years operation shall also be included.

2.1.8.2 Spare parts for the package components shall be identical to originally installed parts.

2.1.9 Site Condition/Environment.

• **2.1.9.1** The purchaser will furnish accurate site conditions to the packager that include but are not limited to: location, climatic conditions (temperature, humidity, wind, barometer, precipitation), airborne atmospheric conditions (any unusual dust or corrosive environment, airborne pollutants, agricultural chemicals, etc.), site elevation, geological and seismic conditions.

• **2.1.9.2** The purchaser will advise the packager of the area classification(s) requirements.

• **2.1.9.3** The purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) in which the equipment must operate.

• **2.1.9.4** Purchaser will state the degree of operator attendance.

2.1.9.5 The package and auxiliaries shall be suitable for operation under the specified conditions. For the purchaser's guidance, the packager shall define in the proposal any special protection that the purchaser is required to supply.

• **2.1.10 Sound Level.** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the packager. The equipment furnished by the packager shall conform to the maximum allowable sound pressure level specified by the purchaser.

• **2.1.11 Emission.** Control of exhaust emission levels of the package shall be a joint effort of the purchaser and the packager. The purchaser will specify the maximum allowable emission levels at the package boundaries. The packager shall state in his proposal expected emission levels consistent with purchaser's specified fuel properties and site operating conditions. The packager shall supply the turbine combustion emission suppression system to meet the specified levels of NO_x, CO, and unburned hydrocarbons in the turbine's exhaust gas.

• **2.1.12 Fuels.** The fuel system shall be operable with the normal fuel or any alternate or starting fuel specified. Purchaser will provide the composition, range of heating values, temperatures, dew point temperature, pressure, contaminants, and other properties of the fuel supply. The packager shall advise the purchaser of the effects of the fuel(s) on turbine package operation and equipment life. When specified, the packager shall provide any fuel treatment equipment required [3.8].

2.2 Package Design.

2.2.1 Packaged Equipment. The packager shall provide, as a minimum, the equipment listed below (referred to herein as a "package") packaged to meet the specified operating conditions. This equipment shall be assembled (packaged) to the maximum extent possible.

a. Baseplate(s).

b. Combustion gas generator.

c. Controls and instrumentation.

d. Couplings and guards.

e. Exhaust collector.

f. Fuel system(s).

g. Lube oil system(s).

h. Power turbine (if separate from gas generator).

i. Starting system.

j. Gas Turbine washing or cleaning system.

k. Vibration monitoring system.

2.2.2 Shipped Loose Equipment. The packager shall provide the accessory equipment listed below to meet the specified operating conditions. This equipment shall be either packaged or shipped loose.

a. Control panel.

b. Inlet ducting.

c. Inlet filtration system.

d. Inlet silencer.

● **2.2.3 Other Equipment.** Any other equipment required will be specified by the purchaser and shall be included in the packager's proposal. Such equipment may include:

a. Combustion emission control system.

b. Driven equipment in accordance with applicable specifications.

c. Enclosure(s) for acoustical, weather, and/or fire protection.

d. Exhaust system (including expansion joints, silencers, structures).

e. Fuel conditioning.

f. Inlet evaporative air cooler.

g. Inlet anti-icing system.

h. Lifting equipment for maintenance.

i. Lifting equipment for shipping and handling.

j. Motor control center.

k. Recuperator or regenerator for turbine performance enhancement.

l. Starting system auxiliaries.

m. Steam or water injection fluid conditioning system.

n. Turbine load train condition monitoring equipment.

o. Uninterrupted power supply for controls, instrumentation, and operation.

p. Waste heat recovery systems.

2.2.4 Preliminary Review. Many factors (such as piping and ducting loads, alignment at operating conditions, supporting structure, and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the packager shall review and comment on the purchaser's piping, ducting, and foundation drawings.

● **2.2.5 Motors and Electrical Components.** Motors, electrical components, and electrical installations shall be suitable for the area classification(s) (class, group, and division) specified by the purchaser on the data sheets and shall meet the requirements of NFPA 70, Articles 500 and 501, as well as local, state, and federal codes specified and furnished by the purchaser.

● **2.2.6 Operating Speed Range.** The output shaft operating speed range of gas-turbine units for mechanical drive applications shall be suitable to meet all operating conditions specified by the purchaser on the data sheets. Where only one operating condition is specified for an application, the minimum speed range for single shaft machines shall be 25 percent (from 80 to 105 percent of rated speed) and the minimum speed range for two or more shaft machines shall be 55 percent (from 50 to 105 percent of rated speed). The turbine shall have satisfactory mechanical performance at all operating conditions specified on the data sheets and within the range among those conditions. The unit shall be capable of operation, without damage, to the trip speed setting at all operating conditions.

2.2.7 Rating Condition. The gas turbine package shall be mechanically designed and satisfactory for continuous service at potential maximum power [1.4.19].

2.2.8 Operating Criteria.

2.2.8.1 The package shall operate on the test stand and on its permanent foundation within the specified acceptance criteria [4.3]. After installation, the acceptance of mechanical and operating performance of the package shall be the joint responsibility of the purchaser and the packager.

2.2.8.2 The purchaser will specify the available utility supplies on the data sheets; the packager shall provide the required utility loads on the data sheets (Appendix A).

2.2.9 Starting Requirements. The package design shall permit immediate starting from any nonrotating condition. Any restrictions shall be defined in the proposal.

2.2.10 Temperature/Speed Limits. Equipment shall be designed to run without damage at any speed up to the highest trip speed in combination with any of the packager's allowable temperatures.

2.2.11 Package Arrangement. The arrangement of the package, including piping, coolers, pumps, and controls shall provide adequate clearance areas and safe access for operation and maintenance.

2.2.12 Maintenance Requirements.

2.2.12.1 All major equipment shall be designed to permit rapid and economical maintenance. Parts such as casing components and bearing housings shall be designed (shouldered or cylindrically doweled) and manufactured to ensure accurate alignment during reassembly. Stationary vanes, nozzles, seals, bearings, diaphragms, gas turbine modules, and the rotating elements shall be replaceable at site. The packager's proposal shall describe the special tooling needed for the above purposes. If the equipment designs do not permit such replacement, the packager shall state in his proposal the procedures required for such repairs.

2.2.12.2 All equipment shall be suitable for periods of idleness up to 3 weeks, under specified site conditions, without requiring any special maintenance procedures.

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

• **2.2.14 Steam or Water Injection.** When specified, the gas turbine shall be designed to permit steam or water injection for either increasing the power capability of the unit or for emission control. The packager shall specify the required quality and quantity of the injection fluid [3.8.5].

2.2.15 Control Requirements. The package control system shall provide for sequenced startup, stable operation, warning of abnormal conditions, monitoring of operation, and shutdowns of the package in the event of impending damage to the unit [3.9].

2.2.16 Special Tools and Fixtures.

• **2.2.16.1** When special tools and fixtures are required to disassemble, assemble, or maintain the package, they shall be included in the quotation and, when specified, furnished as part of the initial supply of the package. For multiple unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the packager. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

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

• **2.2.17 Compartment Enclosure(s).** When specified, suitable enclosure(s) shall be provided to meet purchaser's acoustical, weatherproofing, and/or fire protection requirements. Enclosure(s) shall be designed to ensure the package can meet the maintenance, operation, and service life requirements [3.3].

2.3 Combustion Gas Turbine Drive Train Mechanical Equipment Components.

2.3.1 Combustion Gas Turbine Drivers.

2.3.1.1 The combustion gas turbine driver shall be a current production model suitable for installations in production facilities.

• **2.3.1.2** The Purchaser will specify whether the packager shall supply a combustion gas turbine driver in accordance with API Standard 616 Section 2 or the Manufacturer's Standard. When conflict between API Standard 616 Section 2 and this specification exists, this practice shall apply.

2.3.1.3 The data sheets from Appendix A shall be completed and become a part of the package data sheets.

2.3.2 Couplings and Guards.

2.3.2.1 The packager shall furnish all couplings and guards, including adaptor plates, between the turbine, starting driver, auxiliary gears, and if applicable, load gear and the load equipment.

• **2.3.2.2** When specified, main load couplings, coupling mountings, and guards shall conform to API Standard 671. The coupling make, type, and mounting arrangement shall be agreed upon by the packager and by the purchaser. A spacer coupling shall be used, unless otherwise specified.

• **2.3.2.3** When specified, the packager shall supply a special, equivalent moment type, idling adapter as required for the mechanical running test [4.3.4].

2.3.2.4 Couplings shall be sized for maximum continuous torque based on the potential maximum power capability that can be delivered to a specific coupling.

2.3.2.5 For power generation service, the generator load coupling shall be sized to withstand the worst case of generator fault conditions unless a shear type coupling is provided.

2.3.2.6 Couplings shall be dynamically balanced on an individual component basis and then assembled into a completed coupling which is also dynamically balanced as an assembly as per API Standard 671, paragraph 2.5.3.1, procedure 3.

2.3.2.7 Coupling-to-shaft connections shall be designed and manufactured to be capable of transmitting power at least equal to the maximum continuous torque rating of the coupling.

2.3.2.8 Coupling spacer length shall allow removal and replacement of bearings and seals without disturbing main equipment casings.

2.3.3 Auxiliary Gears.

2.3.3.1 The gas turbine driver may utilize auxiliary gears for starting functions, lubrication drive, liquid fuel pumps, and bearing sump scavenging pumps. Main load gears may utilize auxiliary gearing for main load train lubrication pump drives and starting functions.

2.3.3.2 Auxiliary gears shall comply with AGMA 420 or 421 as applicable, and shall be rated for at least 110 percent of the power transmitted. Tooth surface finish shall be to AGMA quality level 10 or better.

2.3.4 Load Gears.

• **2.3.4.1** Unless otherwise specified, load gears design, testing, and application shall comply with API Standard 613 and the purchaser's specifications. Pertinent design/gear loading data shall be designated by the purchaser on the applicable data sheets shown in Appendix A. Epicyclic/planetary type gear designs and applications shall comply with the applicable paragraphs of API Standard 613, AGMA 420, and AGMA 421.

2.3.4.2 The minimum horsepower ratings of load gears shall be at least equal to the maximum potential power output of the gas turbine per purchaser's stated ambient temperature range. If this results in an excessively large gear/horsepower ratings, packager and purchaser may mutually agree on a lessor size gear/actual gear rating.

• **2.3.4.3** The minimum generator load must also be considered in the design of load gear for turbine-generator sets. The purchaser will specify the minimum generator load.

2.3.5 Driven Equipment.

2.3.5.1 Packager supplied packaged combustion gas turbine driven equipment load-trains typically will be turbo-machinery type with driven equipment such as centrifugal compressors, centrifugal pumps, AC power generators, or combinations thereof.

2.3.5.2 Centrifugal Compressors.

2.3.5.2.1 Unless otherwise specified, centrifugal compressor design, testing, and installation shall be in accordance with API Standard 617 and the purchaser's specifications.

● **2.3.5.2.2** Compressor equipment shall include seal oil or seal gas arrangements. Where seal oil systems are utilized, a combined seal oil/lubrication oil system shall be utilized only with purchaser's approval.

The purchaser will specify on the data sheets whether the seal-oil and lube-oil systems 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.

● **2.3.5.2.3** Compressor performance requirements in including gas flow rates, operating pressure, temperature ranges, and gas composition will be provided by purchaser on the applicable data sheets.

2.3.5.3 Centrifugal Pumps.

2.3.5.3.1 Unless otherwise specified, centrifugal pump design, testing, and installation shall be in accordance with API Standard 610 and the purchaser's specifications.

● **2.3.5.3.2** Centrifugal pump performance requirements in regard to liquid flow rates, operating pressure and temperature ranges, and liquid fluid properties will be provided by purchaser on the applicable data sheet shown in Appendix A.

2.3.5.4 Generators.

2.3.5.4.1 Generators shall be designed and installed per the purchaser's requirements and specifications. Unless otherwise specified, generators shall be a two-bearing, air cooled, AC synchronous design.

● **2.3.5.4.2** Generator rating and electrical hardware and instrumentation requirements to be provided by packager will be specified by purchaser on the applicable data sheet shown in Appendix A.

2.3.5.4.3 Generators shall be designed to meet the applicable requirements of NEMA MG1-22 and ANSI C50.10, C50.12, C50.13, and C50.14 Standards. The generator mechanical design qualities shall be equivalent to those required in API RP 546. Generator rotor dynamics design, assembly, and testing shall be in accordance with this specification's section 2.5 and the Dynamics Section 2.4.7 of API RP 546.

● **2.3.5.4.4** As specified in Appendix A, the packager shall provide equipment as indicated on The Generator Power System one line diagram. The purchaser and packager will agree on the scope of supply and location of the required equipment.

● **2.3.5.4.5** When specified, inspection and testing shall be in accordance with Appendix E

2.3.5.5 Reciprocating Compressors. Gas turbine driven reciprocating compressor packages are not addressed by this specification. The purchaser and packager shall mutually agree upon the unique design issues of torsional pulsation and specific packaging provisions associated with reciprocating compressors.

2.3.6 Vibration and Balance.

2.3.6.1 When shaft displacement type vibration monitoring is used, the following applies: During the shop test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 2.0 mils (50 micrometers), whichever is less:

$$\underline{A} = [12{,}000/\underline{N}]^{0.5} \qquad \text{Equation 1}$$

In SI units, this converts to:

$$\underline{A} = 25.4[12{,}000/\underline{N}]^{0.5}$$

Where:

$\underline{A}$ = amplitude of unfiltered vibration, in mils (micrometers) peak to peak

$\underline{N}$ = maximum continuous speed, in revolutions per minute

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

Note: *These limits are not to be confused with the limits specified in 2.3.6.6 for shop verification of unbalanced response.*

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

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

2.3.6.4 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 percent of the test level calculated from Equation 1 or 0.25 mil (6.4 micrometers), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

2.3.6.5a Where case mounted (Seismic) vibration systems are standard on packaged equipment, the manufacturer(s) shall provide purchaser with the criteria used to define the manufacturer's acceptable vibration limits. These criteria shall include, but not be limited to, the following:

- Locations and types of transducers
- Filtration and signal conditioning
- Operational conditions
- Quoted limits
- Shop/field experience factors from previous/similar units.

2.3.6.5b During the factory test of the assembled aircraft-derivative gas generator/gas turbine, at any steady state speed within the specified operating range, the amplitude of vibration (measured at the manufacturer's standard sensor locations) shall not exceed 50 percent of the manufacturer's published alarm set point value. This limit may be based on filtered or unfiltered data as published by the manufacturer and shall be verified during the factory test. Summary data from previously tested units shall be included to document vibration levels.

2.3.6.6 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. 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 [Appendix C]. The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

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

In SI units, this converts to:

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

Where:

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

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

N = maximum continuous speed, in revolutions per minute

2.3.6.7 The method of balancing a stacked rotor assembly where the rotor is progressively assembled and cannot be removed as a unit, and when paragraph 2.3.6.6 cannot be followed because of rotor design, the following shall apply:

a. All rotating parts shall be component balanced.

b. The assembled rotor shall be check balanced to the limits specified in 2.3.6.6. 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 repeated to achieve the allowable residual unbalance limits.

2.3.6.8 Generator rotor balance shall be done with all rotor armature pieces in place, including the exciter assembly.

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

2.3.6.10 Final residual unbalance levels (inch- ounces/gram-millimeters) shall be recorded with the rotational speed of balance noted and unbalance angle locations indicated for each rotor assembly.

2.3.6.11 Residual magnetism shall not exceed 3 gauss in the rotating and stationary interface areas such as the shaft journals or the bearing sleeve. Residual magnetism in the shaft extension and coupling areas shall not exceed 3 to 5 gauss. Magnetic fields exceeding these values will require demagnetizing to within acceptable levels prior to shipment.

2.4 Critical Lateral and Torsional Speeds Considerations/Responsibilities.

2.4.1 General.

2.4.1.1 This section is concerned with the rotor dynamics of the combustion gas turbine driver as well as the associated driven load-train equipment. Each load-train equipment component manufacturer should be responsible for the acceptable rotor dynamics design of the equipment as an isolated, singular component in accordance with this Section 2.4 and Section 2.5 as well as the requirements of the applicable component standards.

2.4.1.2 When all combustion gas turbine driven equipment components are assembled as a load-train of equipment, individual equipment component rotor dynamic response characteristics can be expected to change from that of the isolated, singular component signature basis. A total load-train rotor dynamics analysis shall be performed to ensure that these changes will not be detrimental to the satisfactory long-term operation of any equipment component.

2.4.2 Packager Responsibility.

2.4.2.1 The packager shall be responsible to insure that the drive-train critical speeds (rotor lateral, system torsional, and blading modes) are compatible with the critical speeds of the machinery being supplied, and that the combination is suitable for the specified operating speed range, including any starting speed detent (hold-point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for his review, included in the technical manual for his guidance [5.2.6], and programmed into the control system to avoid these critical speeds.

● **2.4.2.2** The packager shall be responsible for the lateral and torsional critical speed analysis of the entire equipment system. This speed analysis shall be performed on a total load-train assembly basis. All shaft critical speeds, pertinent modes of exciting frequencies of the driver and driven equipment throughout the start-up and operating speed range, and any external exciting forces, as defined by the purchaser, shall provide specified separation margins to prevent excitation of one by another, and shall provide for an ample range of frequencies within which the supporting foundation's natural frequencies may be designed. This analysis shall be performed in time to permit coordination of the package installation design. Report requirements are specified in 5.2.6.

2.4.3 Critical Speeds.

2.4.3.1 Critical lateral and torsional speeds for driven equipment components shall be at least 10 percent above or below their operating speed range.

2.4.3.2 The dynamics criteria of Section 2.5 shall apply for all hydrodynamic radial type bearing designs.

2.4.3.3 Aircraft derivative type combustion gas turbines generally use antifriction ball and roller type bearings. Rotor dynamic response functions and associated amplitude factors will be different from those of hydrodynamic bearing design turbines. The dynamic criteria of paragraphs 2.5.1, 2.5.2, and 2.5.3 do not apply.

2.5 Dynamics.

2.5.1 General.

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

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

2.5.1.3 When the rotor amplification factor [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 practice, a critically damped system is one in which the amplification factor is less than 2.5.

2.5.1.4 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.

a. Mechanical unbalance in the rotor system.

b. Oil-film instabilities (whirl).

c. Internal rubs.

d. Blade, vane, nozzle, and diffuser passing frequencies.

e. Gear-tooth meshing and side bands.

f. Coupling misalignment.

g. Loose rotor-system components.

h. Hysteretic and friction whirl.

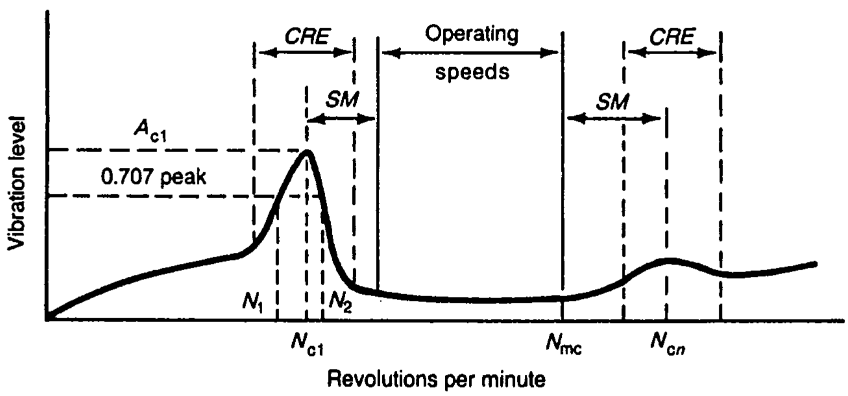
i. Boundary-layer flow separation.

j. Acoustic and aerodynamic cross-coupling forces.

k. Asynchronous whirl.

l. AC power generator electrical unbalance and/or cycle speeds.

2.5.1.5 Resonances of rotor bearing support systems within the packager's scope of supply shall not occur within the specified operating speed range or the specified separation margins, unless the resonances are critically damped.



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

$$= \frac{N_{c1}}{N_2 - N_1}$$

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

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

2.5.2 Lateral Analysis.

2.5.2.1 The packager shall provide a damped unbalanced response analysis for each machine to assure acceptable amplitudes of vibration at any speed from zero to trip.

2.5.2.2 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 packager shall state the assumed support system values or shall use those as provided by the purchaser.
- **b.** Bearing lubricant-film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances, and maximum to minimum clearances.
- **c.** Rotational speed, including the various starting-speed detents, operating speed, and load ranges (including agreed upon test conditions if different from those specified), trip speed, and coast down conditions.
- **d.** Rotor masses, including the mass moment of coupling halves, stiffness, and damping effects (for example, accumulated fit tolerances, fluid stiffening and damping, and frame and casing effects).
- **e.** Asymmetrical loading (for example, partial arc admission, gear forces, side streams, and eccentric clearances).

2.5.2.3 The effects of other equipment in the train shall be included in the damped unbalanced response analysis (that is, a train lateral analysis shall be performed).

2.5.2.4 As a minimum, the damped unbalanced response analysis shall include the following:

- **a.** A plot and identification of the mode shape at each resonant speed (critically damped or not) from zero to trip, as well as the next mode occurring above the trip speed.
- **b.** Frequency, phase, and response amplitude data at the vibration probe locations through the ranges of each critical speed, using the following arrangement of unbalance for the particular mode. This unbalance shall be sufficient to raise the displacement of the rotor at the probe locations to the vibration limit defined by 2.3.6.1.

  The unbalanced weight or weights shall be placed at the location or locations within the bearing span that have been analytically determined to affect the particular mode most adversely (for example, at mid span for translatory modes, or near both ends and 180 degrees out of phase for conical modes). For bending modes with maximum deflections at the shaft's ends, the amount of unbalance shall be based on the overhung mass rather than the static bearing loading.
- **c.** Modal diagrams for each response in item b, above, indicating the phase and major-axis amplitude at each coupling engagement plane, the centerlines of the bearings, the locations of the vibration probes, and each seal area throughout the machine. The minimum design diametral running clearance of the seals shall also be indicated.
- **d.** For the purpose of the verification test [2.5.3], in an attempt to raise the amplitude at the probes to the API vibration limit, an additional plot of a test unbalance, not less than two times or more than eight times API unbalance limits as specified in item b. above (based on static bearing loading for rigid modes or based on overhung mass for bending modes), with maximum deflection at the shaft end, which shall be placed at a location determined by the packager [2.5.3.2.1].
- ● **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.

2.5.2.5 The damped unbalanced response analysis shall indicate that the machine in the unbalanced condition described in 2.5.2.4, item b., will meet the following acceptance criteria [Figure 1].

- **a.** If the amplification factor is less than 2.5, the response is considered critically damped and no separation margin is required.
- **b.** If the amplification factor is 2.5-3.55, a separation margin of fifteen percent above the maximum continuous speed and five percent below the minimum operating speed is required.
- **c.** If the amplification factor is greater than 3.55 and the critical response peak is below the minimum operating speed, the required separation margin (a percentage of minimum speed) is equal to the following:

  $$SM = 100 - [84 + 6/[AF-3]] \quad (2)$$
- **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:

  $$SM = [126 - 6/[AF-3]] - 100 \quad (3)$$
- **e.** The above specified margins of separation are intended to prevent the overlapping of the critical response envelopes into the operating speed range. The margins of separation shall be increased to prevent any actual overlaps.

2.5.2.6 Amplification Factor, for lateral critical speeds, shall not exceed 8 while going through criticals. Values of Amplification Factors less than 5 are preferred. This measurement shall be recorded on deceleration (coast down) with the slowroll (300-600 RPM) total run-out (electrical and mechanical) subtracted by vectoral run-out compensation. This recorded shaft relative data shall include speed, peak-to-peak displacement, and phase angle.

2.5.2.7 The calculated unbalanced peak-to-peak rotor amplitudes [2.5.2.4, 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).

2.5.2.8 If, after the purchaser and the packager 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 packager, subject to the requirements of 2.5.2.7.

2.5.3 Shop Verification of Unbalance Response Analysis.

2.5.3.1 Shop test verification procedures for rotor design unbalance response analysis for the gas turbine, centrifugal compressor, and centrifugal pump rotors shall be in accordance with the applicable sections of API Standards 616, 617, and 610 respectively.

2.5.3.2 Shop test verification procedures for rotor design unbalance response analysis for generator and flexible shaft main load gear elements shall be in accordance with the following:

2.5.3.2.1 The actual critical speed responses, as revealed on the test stand with a rotor unbalance vectorially additive in phase to the residual unbalance of a magnitude in accordance with 2.5.2.4, item d., placed at a location determined by the packager (usually the coupling), shall be the criteria for confirming the validity of the damped unbalanced response analysis.

Note: *It is recognized that the dynamic response of the machine on the test stand will be a function of the agreed-upon test conditions. Unless test-stand conditions duplicate the fields foundation characteristics and the same pressure, temperature, speed and load, the results obtained on the test-stand will not correlate with those obtained during field operations.*

2.5.3.2.2 The parameters to be measured during the test shall be speed and shaft vibration amplitudes with corresponding phase angle. The vibration amplitudes and phase angle from each pair of x-y vibration probes shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major-axis amplitude of each response peak at the probe location shall not allow the vibration limits specified in 2.3.6 to be exceeded. The gain of the recording instrumentation used shall be predetermined and preset before the test so that the highest response peak is within 60-100 percent of the recorder's full scale on the test-unit coast-down (deceleration).

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

Note 2: *The phase on each vibration signal, x or y, is the angular measure, in degrees, of the phase difference (lag) between a phase reference signal (from a phase transducer sensing a once-per-revolution mark on the rotor, as described in API Standard 670) and the next positive peak, in time, of the synchronous (1x) vibration signal. (When proximity probes are used, this is the lag angle between the vibration probe and the high spot on the rotor.)*

Note 3: *The major-axis amplitude is properly determined from a lissajous (orbit) display on an oscilloscope, oscillograph, or equivalent. When the phase angle between the x and y signals is not 90 degrees, the major-axis amplitude can be approximated by* $(x^2 + y^2)^{1/2}$. *When the phase angle between the x and y signals is 90 degrees, the major-axis value is the greater of the two vibration signals.*

2.5.3.2.3 Additional testing per 2.5.3.2.4 will be required if, from the test data described above and/or a phase or amplitude indication in the damped unbalanced response analysis (based on the unbalance conditions described in 2.5.2.4, item b.), it appears that either of the following conditions exists:

a. Any critical response will fail to meet the separation margin requirements [2.5.2.5] or will fall within the operating speed range.

b. The requirements of 2.5.2.7 have not been met.

2.5.3.2.4 Rotors which fail to meet the criteria specified in 2.5.3.2.2 shall require additional testing as follows.

a. Unbalance weights shall be placed as described in 2.5.2.4, item b. Unbalance magnitudes shall be achieved by adjusting the residual unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by 2.5.2.4, item b at the maximum continuous speed; however, the unbalance shall be no less than twice the unbalance limit specified in 2.3.6.6. The measurements from this test, taken in accordance with 2.5.3.2.2, shall indicate the following acceptance criteria for the machine.

   1. Shaft deflections shall not exceed 55 percent of the minimum design running clearances (exclusive of abradable seals) or 150 percent of the allowable vibration limit at the probes, at any speed within the operating speed range (0 to trip), including separation margins [2.5.2.4, item b].

   2. Shaft deflections shall not exceed 90 percent of the minimum design running clearance at any speed outside the operating speed range, including the separation margins.

b. The internal deflection limits specified in Items 1. and 2. above shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 2.5.2.4, 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, not on inspection of seals after testing; however, 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 component manufacturer's new-part tolerance do not constitute damage.

2.5.4 Torsional Analysis.

2.5.4.1 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. Startup conditions such as speed detents (under inertial impedances) and other torsional oscillations.

c. Hydraulic-governor control-loop resonances.

2.5.4.2 The torsional resonances of the complete train shall be at least ten percent above or ten percent below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

2.5.4.3 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 [2.5.4.4]. 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. Identification of these frequencies shall be the mutual responsibility of the purchaser and the packager.

2.5.4.4 When torsional resonances are calculated to fall within the margin specified above (and the purchaser and the packager have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train.

2.6 Materials of Package Construction.

• **2.6.1 General.**

2.6.1.1 Materials of package construction shall be manufacturer's standard for the specified operating conditions. See 3.6.1 for auxiliary piping material requirements. Specific attention shall be given to the need for and extent of corrosion-resistant materials and components as well as the type of protective coating systems for the particular site conditions.

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

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

• **2.6.1.4** The purchaser will specify any corrosive agents present in the motive and process fluids and in the environment, including constituents that may cause stress corrosion cracking.

Note: *When dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material may be created. If such conditions exist, the purchaser and the packager should select materials in accordance with the NACE Corrosion Engineer's Reference Books.*

2.6.1.5 Where mating parts such as studs and nuts of AISI Standard Type 300 stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification.

Note: *Torque loading values will be considerably different with and without antiseizure compound.*

2.6.1.6 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 practices are acceptable. The use of ASTM A-515 steel is prohibited.

2.6.1.7 For the selection of pressure containing materials other than austenitic stainless steel for service below -20°F (-29°C), the packager shall require a Charpy V-notch impact test of the base metal and of the weld joint.

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 minimum tensile properties and 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 coarse-grain practices. The packager shall exercise caution in the selection of materials intended for service between -20°F (-29°C) and 100°F (38°C).*

2.6.2 Welding.

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

2.6.2.2 Welding of piping shall be in accordance with ANSI B31.3.

2.6.2.3 Welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed in accordance with AWS D1.1.

2.6.2.4 The packager 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.

2.6.2.5 Repair welds shall be nondestructive tested by the same method used to detect the original flaw.

2.6.3 Piping and Tubing.

2.6.3.1 Piping and tubing materials shall comply with Table 1 [3.6.1], Minimum Requirements for Piping and Tubing Systems.

2.6.3.2 Piping and tubing materials for sour gas service shall comply with the recommendations of NACE MR-01.

2.6.4 Structural. Carbon steel for structural applications such as baseplates, modules, etc., shall comply with ASTM A-36 as a minimum for plate and structural shapes. Structural steel tubing shall be to ASTM A-500, Grade B, minimum. Structural steel members shall be limited to standard sizes, shapes, and weights per AISC Manual of Steel Construction.

2.6.5 Galvanized Steel. Galvanized material which is to remain unpainted shall be of the hot-dipped type to ASTM A-525 to a minimum of 3 ounces per square foot. Galvanized material which will be subject to a finish coating of paint or similar material shall be of the electro-galvanized type in accordance with ASTM A-591.

2.6.6 Nonmetallic materials such as elastomers shall be compatible with the process or motive fluids with which they come into contact during normal operation or maintenance functions.

2.6.7 Bolting.

2.6.7.1 The quality of bolting for pressure joints including piping shall be determined from the actual bolting temperature as defined by ANSI B31.3 and shall be at least equal to that shown in Table 1, [3.6.1].

2.6.7.2 Nuts shall conform to ASTM A-194, Grade 2 or 2H, for A-193 bolting, and ASTM A-307, Grade B case hardened, for A-307 bolting.

2.7 Nameplates.

2.7.1 A nameplate shall be securely attached at a readily accessible point on the package and on other major pieces of equipment within the package.

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

2.7.3 The purchaser's item number, the vendor's name, the machine's serial number, and the machine's size and type, as well as its minimum and maximum allowable design limits and rating data (including pressures, temperatures, speeds, and power), maximum allowable working pressures and temperatures, hydrostatic test pressures, and critical speeds, shall appear on the machine's nameplate. The purchaser will specify on the data sheets whether customary or SI units are to be shown.

SECTION 3
ACCESSORY SYSTEMS

3.1 Starting Systems.

● **3.1.1** The packager shall furnish the type of starter system specified by the purchaser. Typical starters include electric motors, gas expansion turbines, steam turbines, hydraulic motors, internal combustion engines, air/gas motors, and small gas turbines. All starter units shall be suitable for satisfactory operation with the specified electrical power characteristics, inlet and exhaust steam pressure and temperatures, air/gas or fuel.

3.1.2 Starting units and associated power transmission equipment shall be suitable for the acceleration of the combustion gas turbine unit/driven load equipment train, and for extended operation during purge and compressor cleaning cycles. The packager shall determine the ratings which shall be at least 110 percent of the starting and acceleration torque required by the gas turbine (and the driven equipment train for single shaft machines) from standstill to self-sustaining speed throughout the specified ambient temperature range. Utilities required for the starting system shall be defined by the packager in his proposal.

● **3.1.3** For single shaft machines, anticipated process variations which may affect the sizing of the starter, (such as changes in pressure, temperature or properties of the fluid handled, and special plant start-up conditions) will be specified by the purchaser. For single shaft turbines, the packager shall prepare a speed torque curve for the turbine and driven equipment with the starting driver torque superimposed.

3.1.4 Steam turbines used as starting gas expanders shall be general purpose turbines per API Standard 611. Electric motor starters larger than NEMA frame size shall be in accordance with API RP 541.

3.1.5 Gas expansion starters using flammable gas as motive power shall be designed for zero leakage at the seals.

3.1.6 Packager shall supply any clutches, speed changing gears, torque converters, or other power transmission equipment and controls required for the starting units.

3.1.7 Any starting driver shall disengage automatically and shut down before reaching its maximum allowable speed. The starters normally are disengaged at turbine governing speed and idle, or are at rest during operation. Failure of the starting driver to disengage shall automatically abort the starting sequence.

3.2 Mounting Systems.

● **3.2.1 General.**

3.2.1.1 The package support base shall be of structural steel design and shall be of sufficient strength for shipment and installation, and to transmit equipment generated forces and couples to Purchaser's foundation. The Purchaser will specify the type of foundation on the data sheets. The system shall be designed as a complete package to support all equipment.

3.2.1.2 The packager shall furnish drawings which contains the requirements for mounting all equipment on the foundation.

3.2.1.3 Baseplates refer to the fabricated structures on which equipment is mounted. Baseplates may either be mounted direct to the foundation or on soleplates. Soleplates refer to separable plates which are leveled and fastened to the foundation, then the package is fastened to the soleplates.

3.2.2 Anchoring Systems.

3.2.2.1 When a baseplate is installed directly on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The mounting surfaces on the bottom of the baseplate shall be in one plane to permit use of a single-level foundation.

● **3.2.2.2** When epoxy grout is specified on the data sheets, the vendor shall precoat all the grouting surfaces with a catalyzed epoxy primer applied to degreased near-white metal. The purchaser will specify the primer and the method of application.

3.2.2.3 Mounting surfaces that are not to be grouted shall be coated with a rust preventive immediately after machining.

3.2.2.4 As a minimum, mounting surfaces that are to be grouted shall have 2-inch radiused (50 millimeter) outside corners in the plan view.

3.2.2.5 Anchor bolts will be furnished by the Purchaser. Packager shall specify the size, number, and location of anchor bolts required for the specified method of fastening the package to the foundation.

3.2.3 Baseplate Design.

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

Note: *A baseplate with a nominal length of more than 40 feet (12 meters) or a nominal width of more than 12 feet (3.6 meters) may have to be fabricated in multiple sections because of shipping restrictions. Gross weight shipping restrictions from point of manufacturing to point of destination must also be considered in determining if sectioned baseplates are required.*

● **3.2.3.2** 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.

● **3.2.3.3** When specified, the baseplate shall be suitable for column mounting, with sufficient rigidity to be supported at specified points, without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the packager.

3.2.3.4 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting lug weld joints shall be full penetration, full length continuous weld, and nondestructive tested. Lifting the baseplate complete with mounted equipment shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it. Purchaser and Packager shall mutually agree on lifting arrangements based upon available facilities at Purchaser's site or other limiting factors.

• **3.2.3.5** When specified by the Purchaser, lifting frame(s) and/or spreader bar(s) shall be supplied by the packager to permit single or multipoint lift capability.

• **3.2.3.6** When specified, nonskid decking or grating covering all walk and work areas shall be provided on the top of the baseplate. All deckplate shall be positively attached to each crossing structural member.

3.2.3.7 Baseplate shall be furnished with vertical jack screws adjacent to each anchor bolt.

3.2.3.8 Baseplate(s) shall be provided with drip containment and low point drains.

3.2.4 Equipment Mounting.

3.2.4.1 Axial, lateral, and vertical jackscrews shall be provided for all equipment in the package train. Vertical jackscrews shall be arranged to prevent marring of shimming surfaces.

3.2.4.2 Package train component supports shall be provided with AISI Standard Type 300 Stainless Steel Shim packs, 1/4-1/2 inch (6.3-12.7 millimeters) thick, with jackscrews for easy removal or addition of shims. All shims shall straddle hold-down bolts and jackscrews. Laminated shims are prohibited.

3.3 Enclosure and Fire Protection.

3.3.1 General.

• **3.3.1.1** When specified, an enclosure system shall be supplied consisting 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.

• **3.3.1.2** If sound control is specified, the requirements of paragraph 2.1.10 shall apply. Any special "far field" or neighborhood sound restrictions that are applicable will be specified by the purchaser.

3.3.2 Construction.

3.3.2.1 Enclosures shall be weather proof and dust tight. Water and/or dust leakage through the enclosure wall and roof seams is unacceptable. Panels shall be designed to minimize panel internal moisture buildup and corrosion. Panels shall be moisture resistant; fire resistant; insect, and vermin resistant [2.1.9].

3.3.2.2 Enclosures shall be designed to permit easy on-site maintenance.

3.3.2.2.1 Removable roof sections, side panels, or hinged bulkhead walls shall be provided for heavy maintenance. Construction of maintenance accessways shall permit easy return to the original condition. Caulking is not acceptable.

3.3.2.2.2 Access doors and/or manways shall be provided for routine maintenance and inspection. Double acoustic self adjusting seals shall be used around the perimeter of the accessway. Accessways shall be lockable.

3.3.2.2.3 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.

3.3.2.3 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.

3.3.2.4 Adequate lighting for general observation is to be provided within the enclosure. Lights are to be operated by three-way switches located at the accessway on each side of the enclosure.

3.3.3 Fire Protection.

3.3.3.1 A fire protection system shall be furnished when an enclosure is specified, unless specifically deleted from packager'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.

• **3.3.3.2** The fire suppression system shall be designed in accordance with the applicable NFPA standard. The purchaser will specify any special design considerations to be included in the suppression system, including the specific fire suppression medium.

3.3.3.3 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.

• **3.3.3.4** The fire detection system shall be designed in accordance with NFPA-72E. Rate compensated thermal detection shall be considered the minimum level of detection. Additional levels of detection, such as optical, will be specified by the purchaser, if required.

3.3.3.5 The gas detection system shall be designed in accordance with NFPA-72E.

3.3.3.6 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.

3.3.4 Ventilation and Purging.

• **3.3.4.1** 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. Purchaser will specify on the data sheets fan system redundancy requirements and whether positive or negative pressure is required.

3.3.4.2 Ventilation system shall include air filtration and silencing equipment if required.

3.3.4.3 Fan motors shall be single speed for warm environments. Where climatic conditions exist, which can cause abnormal cooling of the enclosure, two speed fan motors may be used.

• 3.3.4.4 Ventilation and purging flow shall leave the enclosure via a flanged exhaust port(s). Each port shall be equipped with a back draft damper and a fire suppression medium damper. Purchaser will specify if additional ventilation ducting is required.

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

3.4 Air Inlet Systems.

3.4.1 General.

3.4.1.1 The air inlet system shall consist of the following:

a. Inlet filter with an entrance debris screen and weather louver or cowling which minimizes the entrance of driving rain, sleet, or snow.

b. Silencer.

c. Ducting.

d. Expansion joints (as required).

e. Pressure drop test connections at the gas turbine inlet.

f. Differential pressure indicator to indicate differential pressure between ambient and the turbine inlet flange, including two high differential pressure alarm switches (alarm and shutdown).

g. Off-line washing system.

• 3.4.1.2 Optional features, when specified, shall include:

a. Anti-icing system.

b. Evaporative cooler with downstream moisture separation.

c. Insect screens.

d. On-line washing system.

e. Walkways, handrails, platforms, and ladders required for access and maintenance.

3.4.1.3 Unless otherwise specified, the inlet system shall be designed for a maximum total pressure drop of 4 inches (102 mm) water with a clean air filter and not less than 110 percent of the air flow at site rated power.

3.4.1.4 Unless otherwise specified, provision shall be made to permit maintenance of inlet filter media during operation of the turbine.

3.4.1.5 Bolts, rivets, or other connectors that can become loose and be carried in the air stream shall not be used in the inlet system downstream of the. final filter media.

3.4.1.6 Unless otherwise specified, reinforced coarse mesh, 1/4 to 1/2 inch (6.4 to 12.7 millimeter) stainless steel screen shall be provided upstream of the gas turbine air inlet. The actual location shall be mutually agreed upon by the packager and the purchaser, considering cleaning systems, access plates, vaned elbows, and aerodynamic disturbance at the bellmouth entrance.

• 3.4.1.7 When specified, all metallic air path components shall be 304 stainless steel.

• 3.4.1.8 When carbon steel air path components are provided, corrosion protection of the filter, ducting, and silencer is required. When specified, all carbon steel shall be hot dipped galvanized per ASTM A-123. Painting of hot dipped galvanized is not permitted. Protective material or coating and details of the surface preparation proposed shall be submitted by the packager for approval with proposal. Galvanized carbon steel components are not recommended in marine or coastal environments.

• 3.4.1.9 The purchaser will specify whether the filter house is to be at grade level or elevated. If elevated, the packager shall provide all structural support to grade.

3.4.1.10 All components of the inlet air system, including external structural supports, walkway platforms, etc, which require field assembly and welding shall be prefitted and marked for ease of reassembly at site.

3.4.2 Inlet Filters.

• 3.4.2.1 The purchaser will specify the type of inlet filtration, such as inertial type separator, media filters, self cleaning filter, pad type prefilters, or combinations thereof. If single stage filtration only is specified, the purchaser will specify if provisions are to be made for future addition of extra stages. Debris screens and weather louvers shall not be considered stages.

3.4.2.2 Packager shall provide in his proposal the filter system performance data as required on data sheets.

3.4.2.3 Unless otherwise specified, a high efficiency mist eliminator shall be furnished as the first stage for marine environments. Non absorbent type filter elements such as glass or polypropylene fiber shall be provided.

3.4.2.4 All filter systems require the following design features:

a. All wiring and conduit located downstream of the air filter elements shall be outside of the airpath.

b. All supporting structural steel shall be of bolted and welded design.

c. Modular construction with each module fully factory assembled, wired, and plumbed. Each module shall have lifting provisions to be used for loading and unloading and for lifting into the final assembled position.

d. All seams and joints on the clean air side of each filter system shall be airtight. All joints shall be continuously seal welded.

3.4.3 Inlet Silencers.

• 3.4.3.1 Silencer attenuation shall provide the ability to meet the system noise limitations specified by the purchaser. [2.1.10].

3.4.3.2 Silencers shall be flanged and sufficiently rigid to be supported only by the end flanges when mounted in a horizontal or vertical duct system.

3.4.3.3 The construction of the silencer baffles shall prevent the entry of the baffle packing material into the air stream.

3.4.3.4 Perforated plate elements shall be constructed of stainless steel.

3.4.3.5 The silencer shall be designed to prevent damage resulting from acoustical or mechanical resonances.

3.4.3.6 Lifting provisions shall be incorporated on the silencer for handling.

3.4.4 Inlet Ducting.

3.4.4.1 The duct system shall be arranged for the smallest number of changes in direction. Turning vanes shall be provided at changes in direction when required to ensure uniform flow distribution at the gas turbine flange. The leading and trailing edge of each vane shall be tapered and smooth. Vanes shall be attached to the duct by a continuous weld and shall be designed to avoid resonance conditions.

3.4.4.2 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).

3.4.4.3 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 unit maintenance. Ducts shall be sufficiently rigid to avoid vibration.

Note: *Carbon Steel Plate of 3/16 inch (4.8 millimeters) to 3/8 inch (9.5 millimeters) thickness is generally used for this purpose.*

3.4.4.4 Access shall be provided in each duct adjacent to the gas turbine inlet flange to allow final cleaning and inspection of the entire duct system before operation. Covers, if required, shall be designed to permit their removal at any time without risk of fasteners or other objects being ingested by the gas turbine. They shall be gasketed and secured to ensure positive leakproof closure.

3.4.4.5 Gas tight expansion joints shall be provided to remove all loads between the ducting and gas turbine inlet flanges. These joints shall accommodate the relative movement of the ducting, regenerator (if any), and gas turbine in vertical and horizontal directions.

3.4.5 Evaporative Cooling System.

• **3.4.5.1** When specified, an evaporative cooling system shall consist of the cooler media, pump, if required, sump, drains, wiring and all necessary controls for water circulation and cooler control.

3.4.5.2 Evaporative cooler performance shall be based on the maximum possible airflow and the most severe site environmental conditions. The cooler system shall be designed to prevent liquid carryover. Cooler percent efficiency as stated on the data sheet is defined as:

$$\text{Efficiency} = 100\ \frac{T_d - T_e}{T_d - T_w}$$

Where: T_e = Exit dry bulb temperature

T_d = Entering dry bulb temperature

T_w = Entering wet bulb temperature

3.4.5.3 A corrosion resistant inertial mist eliminator or coalescing element shall be provided in the ducting downstream of the evaporative cooler. The mist eliminator or coalescer shall be selected to minimize moisture carryover from the inlet air stream.

3.4.5.4 Cooler water circulation shutdown shall occur on air temperature control. A temperature probe shall be provided to automatically shutdown water circulation when ambient temperatures are less than 50°F (10°C).

3.4.5.5 All evaporative cooler metallic housing and internal structural support shall be stainless steel. All downstream air path components shall be 304 stainless steel.

3.4.5.6 The evaporative cooler, mist eliminator or coalescer, and exit ducting shall be designed for complete drainage. The bottom of each shall slope towards a flush drain. Protrusions or standpipes at the drain nozzles are not permitted. Each drain nozzle shall be arranged to prevent unfiltered air from being drawn into the ducting. Emergency overflow capability is required in addition to the primary drain system.

• **3.4.5.7** When required or specified, walkways, handrails, access ladders, and manways shall be provided to service both upstream and downstream of the evaporative cooler media, mist eliminator or coalescer, and ducting downstream of the cooler.

3.4.5.8 The packager shall specify the quality and quantity of the evaporative cooler water that is necessary to minimize cooler and water system operating problems.

3.4.6 Water Wash System.

3.4.6.1 The packager shall provide a water wash system for offline water washing of the gas turbine compressor section. The packager shall provide fluid quality and quantity and utility requirements with the proposal. Valved drains shall be provided in the inlet plenum and exhaust plenum. The packager shall provide access to the inlet plenum for compressor inlet bell mouth area inspection. The control system shall provide for necessary instrument and control overrides for the wash cycle to prevent its use while the turbine is in service.

• **3.4.6.2** When specified, the packager shall also provide a complete online washing system. The packager shall provide adequate window(s) and flush mounted lighting if required in the inlet plenum to allow visual observation of the online spray pattern as it enters the inlet bell mouth area of the compressor section of the gas turbine. Walkways or access ladders when specified shall extend to window locations, and the window shall be positioned to allow viewing from such walkways or ladders. When the online system is permanently installed in the package or when it uses the same equipment as the offline system, the packager shall provide fail-safe control logic which will not allow either operation to be improperly performed.

3.4.6.3 The water wash system(s) shall be fully described in the proposal including the system schematic [Appendix B].

3.4.6.4 The packager shall provide water wash system operational procedures with the proposal [5.2.3].

3.4.7 Anti-icing System.

● **3.4.7.1** When specified by purchaser, the packager shall provide an automatic anti-icing system at the face of the inlet air filter. Purchaser will indicate the preferred heating medium on data sheets. If gas generator bleed air is to be used, the packager shall indicate its effect on package performance [Appendix B].

3.4.7.2 When anti-icing system is not specified by the purchaser the packager shall evaluate the atmospheric conditions stated on the data sheets to determine the need for an anti-icing system.

3.5 Exhaust System.

● **3.5.1** When specified by the purchaser as a simple cycle application, a complete exhaust system shall be furnished consisting of the following:

a. Turbine-to-exhaust duct expansion joint.

b. Exhaust silencer.

c. Exhaust ducting.

d. Exhaust system structural supports.

e. Exhaust drains.

● **3.5.2** The purchaser will specify special design considerations such as:

a. Insulation requirements for areas where personnel protection is required.

b. Exhaust system discharge flange orientation, location, and installed configuration.

c. Pressure drop associated with purchaser supplied connected equipment.

d. Emission sampling port(s).

3.5.3 For regenerative cycle gas turbines, the packager shall supply and prefit the regenerator, the necessary air piping and exhaust ducting between the turbine and regenerator, including all required expansion joints, supports, structures and necessary insulation and controls.

3.5.4 The basic material for construction of the exhaust system shall be hot rolled carbon steel AISI 1020 or equal for metal service temperatures of -15°F to 850°F. If metal temperatures fall below this range for extended periods of time, the use of low temperature carbon steel such as ASTM A662 may be used. If metal temperatures exceed 850°F for extended periods of time, use of a more corrosion resistant steel shall be provided.

3.5.5 Perforated plate shall be constructed of 400 series stainless steel except where corrosive environment may produce stress corrosion cracking.

3.5.6 Components of the exhaust system shall be flanged for ease of installation and maintenance. All components shall be furnished with suitable lifting provisions.

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

3.5.8 The exhaust joints shall be constructed of metal or high temperature fabric. If fabric is utilized, it shall be multi-layer reinforced with nickel-alloy wires. Expansion joints shall have an internal liner to prevent undue flutter, joint deterioration, or pressure drop. The fabric shall be replaceable without removal of major components.

3.5.9 Access shall be provided in the exhaust system to allow for cleaning and inspection of the exhaust system.

3.5.10 Structural supports shall be furnished for the portion of the exhaust system provided by the packager. These supports shall be designed to allow for thermal growth and to reduce duct loads at the gas turbine flanges to within manufacturers specified limits. The ducting and supports shall be designed to remain stationary when duct sections near the gas turbine are removed to provide access for gas turbine maintenance.

3.6 Piping.

3.6.1 General.

3.6.1.1 Aircraft derivative power turbines and gas generators shall be provided with connections that are compatible with the requirements of MIL-E-5007 and MIL-STD-1534. These machines use flexible connections with stainless steel wire overbraid. Brazed end fittings are prohibited.

Design of all piping systems shall achieve the following:

a. Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.

b. Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.

c. Installation in a neat and orderly arrangement adapted to the contour of the machine and not obstructing access openings.

d. Elimination of air pockets.

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

3.6.1.2 Piping design and joint fabrication, examination, and inspection for packaged equipment shall be in accordance with ANSI B31.3.

3.6.1.3 Piping systems are classified as the following services and shall comply with the requirements of Table 1.

a. **Group I:**
   1. Sealing fluid.
   2. Gland and flushing fluid.
   3. Recirculation fluid.
   4. Balance gas.
   5. Buffer gas.
   6. Fuel gas or oil.
   7. Drains and vents.
   8. Primary process streams.

b. **Group II:**
   1. Sealing steam.
   2. Drains and vents.

c. **Group III:**
   1. Cooling water.
   2. Drains and vents.

TABLE 1
MINIMUM REQUIREMENTS FOR PIPING AND TUBING SYSTEMS

SYSTEM	GROUP I NON-FLAMMABLE/ NON-TOXIC	GROUP I FLAMMABLE/ TOXIC	GROUP II ≤75 PSIG	GROUP II >75 PSIG	GROUP III	GROUP IV
Pipe	Seamless[a]	Seamless[a,b]	Seamless[a]	Seamless[a]	ASTM A120 SCH. 40, Galvanized to ASTM A153	ASTM A312, Type 304 or 316 Stainless Steel[b]
Tubing[c]	Seamless ASTM A269 Stainless Steel	Seamless ASTM A269 Stainless Steel	Seamless ASTM A269 Stainless Steel	Seamless ASTM A269 Stainless Steel	Seamless ASTM A269 Stainless Steel	Seamless ASTM A269 Stainless Steel
All Valves	Carbon Steel Class 800 S.S. Trim	Carbon Steel Class 800 S.S. Trim	Carbon Steel Class 800 S.S. Trim	Carbon Steel Class 800 S.S. Trim	Bronze Class 200	Carbon Steel Class 800 S.S. Trim
Gate and Globe Valves[d]	Bolted Bonnet and Gland	Bolted Bonnet and Gland	Bolted Bonnet and Gland	Bolted Bonnet And Gland	—	Bolted Bonnet and Gland
Pipe Fittings and Unions	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	ASTM A338 and A197, Class 150 Malleable Iron, Galvanized to ASTM A153	Stainless Steel (see 3.6.2.2)
Tube Fittings	300 Series Stainless Steel	300 Series Stainless Steel	300 Series Stainless Steel	300 Series Stainless Steel	300 Series Stainless Steel	300 Series Stainless Steel
Fabricated Joints ≤1-1/2 Inches	Threaded	Threaded[e]	Threaded	Threaded[e]	Threaded	Butt Welded or Slip-on/Flanged
Fabricated Joints ≥2 Inches	Butt Welded	Butt Welded	Butt Welded	Butt Welded	Purchaser to Specify	Butt Welded/ Flanged
Gaskets	Type 304 or 316 Stainless Steel Spiral Wound	Type 304 or 316 Stainless Steel Spiral Wound	Type 304 or 316 Stainless Steel Spiral Wound	Type 304 or 316 Stainless Steel Spiril Wound	Type 304 or 316 Stainless Steel Spiral Wound	Type 304 or 316 Stainless Steel Spiral Wound
Flange Bolts — Studs — Nuts	ASTM A193 Grade B7 ASTM A194 Grade 2H	ASTM A193 Grade B7 ASTM A194 Grade 2H	ASTM A193 Grade B7 ASTM A194 Grade 2H	ASTM A193 Grade B7 ASTM A194 Grade 2H	ASTM A193 Grade B7 ASTM A194 Grade 2H	ASTM A193 Grade B ASTM A193 Grade 2H

NOTE: *Carbon Steel piping shall conform to ASTM A53, Grade B; ASTM A106, Grade B; ASTM A524; or API Specification 5L Grade A or B. Carbon Steel fittings, valves and flanged components shall conform to ASTM A105 and A181. Stainless Steel piping shall be seamless in accordance with ASTM 312 or electric-fusion welded in accordance with ASTM A358.*

[a] Schedule 160 Carbon Steel for diameters of 3/4-inch and smaller; Schedule 80 for diameters from 1-inch to 1-1/2 inches; Schedule 40 for diameters of 2-inch and larger.

[b] Schedule 40S Stainless Steel for all diameters.

[c] 1/4-inch diameter X 0.035-inch wall, 3/8-inch diameter X 0.049-inch wall, 1/2-inch diameter X 0.065-inch wall, 3/4-inch X 0.095-inch wall, or 1-inch diameter X 0.109-inch wall. See Table 2, Minimum Tubing Wall Thicknesses (Control/Instrument Air).

[d] For primary ANSI service pressure ratings above 900 pounds per square inch gage (62 bar gage), block valves may be of welded bonnet or no-bonnet construction with a bolted gland. These valves shall be suitable for repacking under pressure.

[e] Threaded joints require seal welding; however, seal welding is not permitted on cast iron equipment, on instruments, or where disassembly is required for maintenance. Seal-welded joints shall be made in accordance with ASME B31.3.

d. **Group IV:**

1. Lubricating oil.
2. Control oil.
3. Drains and vents.
4. Steam and/or water injection.

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

3.6.1.4.1 The packager shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any oil console base area, or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. Unless otherwise specified, the purchaser will furnish only interconnecting piping between equipment groupings and off-base facilities.

3.6.1.5 The design of piping systems shall achieve the following:

a. Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.

b. Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.

c. Installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access openings.

d. Elimination of air pockets by the use of valved vents or nonaccumulating piping arrangements.

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

3.6.1.6 Pipe threads shall be taper threads in accordance with ASME B1.20.1. Flanges shall be in accordance with ANSI B16.5. Slip-on flanges are permitted only with the purchaser's specific approval. Socket-welded construction is not permitted.

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

3.6.1.8 Where space does not permit the use of 1/2, 3/4, or 1-inch pipe, seamless stainless steel tubing may be furnished in accordance with Table 1.

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

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

3.6.1.11 Welding shall be performed by operators and procedures qualified in accordance with Section IX of the ASME Code.

3.6.1.12 Pipe plugs shall be solid, steel plugs furnished in accordance with ANSI B16.11. As a minimum, these plugs shall meet the material requirements of the adjoining fitting. Plugs that may later require removal shall be of corrosion- resistant material.

3.6.2 Oil Piping.

3.6.2.1 Gravity oil return piping shall be sized to run no more than half full when flowing and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously toward the reservoir. If possible, laterals, not more than one in any transverse plane should enter drain headers at 45- degree angles in the direction of the flow.

3.6.2.2 Nonconsumable backup rings and sleeve-type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that could accumulate dirt.

3.6.3 Instrument Piping.

3.6.3.1 The packager shall supply all necessary piping, valves, and fittings for instruments and instrument panels.

3.6.3.2 Beyond the initial isolating valve, 1/2-inch piping, tubing valves, and fittings may be used. Separate secondary block and bleed type isolating valves are required for each instrument on a common connection. Where a pressure gauge is to be used for testing pressure alarm or shutdown switches, common connections are required for the pressure gauge and switches.

3.6.3.3 Control-air and instrument tubing shall be ASTM A269 stainless steel. Tubing thicknesses shall meet the requirements of Table 2.

Table 2
Minimum Tubing Wall Thicknesses
(Control and Instrument Air)

Nominal Tubing Size (inches)	Minimum Wall Thickness	
	Inches	Millimeters
1/4	0.035	0.89
3/8	0.049	1.25
1/2	0.065	1.65
3/4	0.095	2.41
1	0.109	2.77

3.6.4 Water Injection Piping System.

3.6.4.1 Piping, fittings, valves, and tubing materials for steam/water injection into combustion systems shall be 300 series stainless steel.

3.6.5 Process Piping.

● **3.6.5.1** The extent of process piping to be supplied by the packager will be specified by the purchaser.

● **3.6.5.2** When specified, the packager shall review all piping, appurtenances (intercoolers, aftercoolers, separators, knockouts, air intake filters, and expansion joints), and vessels connected immediately upstream and downstream of the equipment components and their supports. The purchaser and the packager shall mutually agree on the scope of this review.

3.7 Oil Systems.

3.7.1 In general, oil systems shall comply with the intent of API 614 "Lubrication, Shaft-Sealing, and Control Oil Systems for Special Purpose Applications". However, in keeping with the package concept, strict compliance with the lubrication systems requirements of API 614 may not be practical. Deviations from this specification may be applicable and acceptable in the following areas: reservoir retention time, synthetic oil supply temperature, reservoir material, drain system slopes, twin oil coolers, and instrumentation requirements. All deviations from API 614 proposed by the packager require purchaser approval.

3.7.2 The lubrication system providing oil to the drive train components (gas turbine, main load drive gear, and driven equipment) may be a single common system or two separate systems. One of the two systems may be dedicated to an aircraft derivative gas turbine which uses a synthetic lubricant. The other system which serves the remainder of the drive train components shall use a mineral oil based lubricant. Synthetic and mineral oil systems, including vents and drains, shall be segregated.

3.7.3 The mineral oil based system may be used to supply the compressor sealing requirements (if applicable) with approval of the purchaser. Otherwise a separate seal oil system will be provided for compressor applications in compliance with API 614 and API 617. [2.3.5.2]

3.7.4 The packager shall provide a complete description of the lubrication systems (and seal oil system, if required) in the proposal including schematic diagrams and material lists. [5.1]

3.7.5 Unless otherwise specified, a pressurized oil system(s) shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the following:

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

b. The continuously lubricated couplings.

c. The governing and control-oil system.

d. The seal-oil system.

e. The hydraulic oil system for hydraulic starter(s) when required.

● **3.7.6** Where oil is supplied from a common system to two or more machines (such as a compressor, a gear, and a turbine), the oil's characteristics will be specified on the data sheets by the packager 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 ISO Grade 32 or 46, as specified in ISO 3448.*

3.7.7 Pressure lubrication systems other than those described in API Standard 614 shall consist of the following as a minimum:

a. Supply and return system.

b. Oil cooler (when required).

c. Full flow 10 micron (nominal) filter.

d. Low lube-oil pressure switch-shutdown.

e. Steel oil-containing pressure components.

f. Main oil pump, full capacity, separately driven, and automatically controlled when the package main oil pump is not shaft driven.

g. Standby (spare) pumps that are enclosed in reservoir may have cast iron/nodular iron pump cases.

h. Prelube/postlube/coast down/cool down lubrication system capability shall be provided by packager when required.

3.8 Fuel System.

3.8.1 General.

3.8.1.1 The packager shall supply a complete system for receiving fuel from the purchaser. The fuel system shall be operable with the normal fuel or any specified alternative or starting fuels.

● **3.8.1.2** The purchaser will include the grade, type, composition, range of heating values, temperature(s), delivery pressure(s) and contaminants of the proposed fuel in the inquiry specification.

3.8.1.2.1 The contaminants likely to be found in fuel gas depend on the kind of gas involved, such as pipeline natural gas and produced gas. Some of the contaminants that are likely to be found include:

a. Water and Gas Hydrates.

b. Sand, iron oxides, and other solids.

c. Naphthalene.

3.8.1.2.2 Concentrations of hydrogen sulfide, sulfur dioxide, sulfur trioxide, total sulfur, alkali metals, chlorides, carbon monoxide, and carbon dioxide are corrosive agents that will cause elevated temperature corrosion of turbine nozzles and blading materials and ambient temperature corrosion of fuel control valves and systems.

3.8.1.2.3 Total sulfur content must also be considered to protect any equipment downstream of exhaust from corrosion.

3.8.1.3 The ignition system shall include an ignition transformer and igniter plugs. Ignition shall be automatically de-energized and fuel flow stopped if the turbine fails to establish combustion.

3.8.1.4 Fuel 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.

3.8.2 Gaseous Fuel.

3.8.2.1 The packager shall advise the purchaser of maximum/minimum fuel temperature and pressure required at the packager's inlet fuel gas connection.

Note: *Gas must be free of liquids and solids at the purchaser's connection to the package. Special provisions, such as separators or knockout drums by the purchaser, may be required to eliminate condensate in situations where condensation could occur.*

● **3.8.2.2 Heating Value.** The range of heating values of each gas will be specified by the purchaser. For variations in heating value of more than ten percent, the rate of change will be specified by the purchaser as special equipment may be required.

3.8.2.3 Fuel Gas System.

3.8.2.3.1 A gaseous fuel system shall include:

a. "Y" type fuel strainer(s).

b. Necessary instrumentation.

c. A manifold and nozzles.

d. Two fuel shutoff valves with an intermediate vent valve for automatic operation and system purging prior to starting.

e. A fuel control valve.

f. A fuel gas pressure regulator if required.

h. Necessary additional instrumentation.

● **3.8.2.3.2** If the fuel gas pressure required by the packager is higher than that available, a fuel gas compression system will be furnished by the packager when specified by purchaser. Packager shall state the maximum allowable fuel gas temperature supplied by the Purchaser.

3.8.3 Liquid Fuel.

3.8.3.1 A liquid fuel system shall include:

a. Duplex fuel filters with a continuous flow transfer valve.

b. Fuel charge pump.

c. Atomizing air compressor (if required by packager).

d. Two fuel shutoff valves for automatic operation.

e. Necessary instrumentation.

f. Fuel control valve.

g. Fuel flow dividers if required.

h. Fuel nozzles and manifold.

3.8.3.2 To prevent coking and plugging, the packager's design shall include facilities to purge or drain liquid fuel from the fuel manifold system.

3.8.3.3 Duplex fuel filters shall be accessible and capable of being cleaned while in operation. The transfer valve shall have a carbon steel or stainless steel body with stainless steel plugs and plug jacking devices.

3.8.4 Dual Fuel Operation.

● **3.8.4.1** When specified, the gas turbine shall be provided with the necessary equipment to permit normal (starting and continuous) operation on either of the fuels; ie., 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.

3.8.4.2 The dual fuel system shall provide smooth, bidirectional fuel transfer with a maximum of 10% speed and/or load variation.

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

3.8.4.4 Unless otherwide specified, the liquid fuel charge pump shall be motor driven and located outside the turbine enclosure.

3.8.4.5 The Packager shall provide a project specific flow diagram, complete with a bill of material and a written technical description of the dual fuel system, with the proposal. Water/Steam injection requirements during fuel transfer shall be stated in the technical description [Appendix B].

3.8.5 Water/Steam Injection Operation.

● **3.8.5.1** When specified, the gas turbine shall be provided with the necessary equipment to permit water or steam injection for NOX suppression and or power augmentation.

3.8.5.2 The water/steam injection system shall be capable of providing the specified level of NOX suppression at all levels of power output from minimum load to full load.

3.8.5.3 The Packager shall provide a project specific flow diagram, complete with a bill of material and a written technical description of the water/steam injection system, with the proposal [Appendix B].

3.8.5.4 Water/Steam quality and supply requirements shall be stated in the proposal [Appendix B].

3.9 Controls and Instrumentation.

3.9.1 General.

● **3.9.1.1** All controls and instrumentations shall be suitable for the specified electrical area classification [Appendix A].

3.9.1.2 The control system shall provide for startup, stable operation, warning of abnormal conditions, monitoring of operation, and safe shutdown of the package.

● **3.9.1.2.1** When specified, the control system shall be capable of receiving an isolated signal to control the turbine speed to match process requirements (signal from purchaser's controller).

3.9.1.2.2 For constant speed operation, the control system shall be capable of holding a constant speed +/-0.25% at any load (0 - 100%) during steady state operation.

● **3.9.1.3** When specified, the control system shall be designed to maintain operation and unit protection for a purchaser specified time period in the event of interruption of utility AC power.

● **3.9.1.4** When specified, the control system shall have fault tolerant features to maximize unit availability.

Note: *Fault tolerant systems may incorporate redundant or triplicated hardware and software depending upon the critical nature of the application. Hot backup (redundant) controllers, coincident (error checking) software, and voting logic (triplex) systems may be specified in order to provide uninterrupted operation with the presence and acknowledgement of system faults. These systems are to be employed without degradation of monitoring or protective functions.*

3.9.1.5 The packager shall fully describe the control system in the proposal [Appendix B].

3.9.2 Starting Control.

3.9.2.1 Unless otherwise specified, the starting sequence of the package will be automatic from operation initiation to idle conditions.

3.9.2.2 The starting sequence will provide for safe and reliable starts and will be designed by mutual agreement of the purchaser and packager [2.1.4, 2.2.9].

• **3.9.2.3** When specified, the packager shall provide the capability to start the package without the availability of utility AC power (black start).

3.9.2.4 The packager will provide details of the starting control logic in the proposal [Appendix B].

• **3.9.3 Instrument and Control Panel.**

3.9.3.1 Local and/or remote instrument and control panels shall be provided as specified on the data sheets [Appendix A].

3.9.3.2 Panels supplied with the package shall not interfere with removal of major pieces of equipment from the package skid.

3.9.3.3 Intrinsically safe wiring shall be run in separate conduits and terminated in separate terminal boxes, from non-intrinsically safe wiring.

3.9.3.4 The packager shall include 20% spare terminals and conductors in each terminal box.

3.9.3.5 The packager shall include 20% spare alarm and shutdown capacity in the control panel. These shutdowns or alarms are intended for the purchaser. To use these alarms and shutdowns, the purchaser will provide a contact opening or closure to activate the circuit.

3.9.3.6 The shutdown circuits shall be fail-safe. In the event of a loss of signal from a transmitter, transducer or circuit continuity (a circuit with a switch) the unit shall shutdown safely and annunciate the cause.

3.9.3.7 The annunciation of alarms and shutdowns shall be sequential so that the causes of shutdowns show in the same sequence as the actual event.

3.9.3.8 Circuits for A.C. and D.C. shall be separated, installed in separate conduit, and terminated in separate terminal boxes. Terminal boxes and circuits shall be labeled A.C. or D.C.

3.9.3.9 Wiring to switches and instruments on the unit shall be from terminal box(s) mounted on the unit. Wiring shall be installed in conduit. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification. All non-explosion proof control cabinets for outdoor locations containing 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.

3.9.4 Instrumentation.

3.9.4.1 A means of measuring and displaying each shaft speed shall be provided for turbine/compressor or turbine/pump packages. Measuring and displaying may be a part of the turbine control and monitoring system or by separate tachometer mounting.

3.9.4.2 Each overspeed trip system shall have a minimum of two sensing elements. An overspeed detection from any sensor shall cause gas turbine to shut down.

3.9.4.3 Temperature Gauges.

3.9.4.3.1 Dial type temperature gauges shall be heavy duty and corrosion resistant. The face shall be at least 5 inches (127 millimeters) in diameter and bimetallic or gas filled with black printing on a white background.

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

3.9.4.4 Thermowells. Temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines of 1-1/2 inch and larger shall be furnished with 3/4-inch NPT AISI Standard Type 300 Series stainless steel separable solid-bar thermowells.

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

3.9.4.6 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, 4-1/2 inch (114 millimeter) dials and 1/2-inch National Pipe Thread (NPT) male alloy steel connections. Black printing on a white background is standard for gauges. Fluid-filled gauges shall be furnished in all locations except for differential pressure indications. Gauge ranges shall preferably be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 percent. Each pressure gauge shall be provided with a device such as a disk insert or blowout back designed to relieve excess case pressure.

3.9.4.7 Solenoid Valves. Direct acting solenoid operated valves, when used 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. Direct acting Solenoid valves may be used when redundancy is provided.

3.10 Electrical Systems.

• **3.10.1** The characteristics of electrical power supplies, such as those used 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. It is recommended that pilot lights be installed on appropriate control panels.

• **3.10.2** Electrical controls may be either AC or DC and shall be described in packager's proposal. When DC power is specified for controls, a DC power supply must be provided by the packager. The DC power supply shall include a battery charger and batteries (nickel-cadmimum or lead-calcium recommended) sized to provide power to the system for the highest electrical load and duration of load requirement [3.9.1.3]. When AC power is specified, an uninterruptable power supply (UPS) system shall be provided to meet the requirement of 3.9.1.3.

3.10.3 Power and control wiring within the confines of the baseplate shall be resistant to oil, heat, moisture, and abrasion. Stranded conductors shall be used within the confines of the baseplate and in other areas subject to vibration. Thermocouple and control panel ribbon cable wiring may be solid conductor. Wiring system shall be suitable for environmental condition specified [2.1.9.1].

3.10.4 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.

3.10.5 To facilitate maintenance, clearance shall be provided for all energized parts (such as terminal blocks and relays) on turbine and auxiliary equipment.

● **3.10.6** Electrical materials, including insulation, shall be as corrosion resistant and non-hygroscopic as possible [2.1.1]. When a tropical location is specified, materials shall be given the treatments specified below:

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

3.10.6.2 Unpainted surfaces shall be protected from corrosion by plating or other suitable coating.

3.10.7 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 electromagnetic interference. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a liquid tight flexible metallic conduit or explosion proof flexible fittings (as applicable to the area classification). Flexible conduit shall be long enough to permit access to the unit for maintenance without removal of the conduit.

SECTION 4
INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

4.1 General.

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

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

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

● **4.1.4** The purchaser will specify the extent of his participation in the inspection and testing.

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

4.1.4.2 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.

4.1.4.3 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 packager shall proceed to the next step.

4.1.5 Equipment for the specified inspection and tests shall be provided by the packager.

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

4.1.7 At least six weeks before the first scheduled test, the packager shall submit to the purchaser, for his review and comment, detailed procedures for all running tests, including acceptance criteria for all monitored parameters.

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

4.2 Inspection.

4.2.1 General.

4.2.1.1 The packager shall keep the following data available for at least 5 years for examination by the purchaser or his representative upon request.

● a. Specified certification of materials, such as mill test reports.

b. Purchase specifications for all items on bills of materials.

c. Test data to verify that the requirements of the specification have been met.

d. Results of documented tests and inspections, including fully identified records of all heat treatment and radiography.

● e. When specified, final-assembly maintenance and running clearances.

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

● **4.2.1.3** In addition to the requirements of 2.6.2.1 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.

4.2.2 Material Inspection.

● **4.2.2.1 General.** When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 through 4.2.2.5 shall apply unless other criteria are specified by the purchaser. Cast iron may be inspected in accordance with 4.2.2.4 and 4.2.2.5. Welded cast steel, and wrought material may be inspected in accordance with 4.2.2.2 through 4.2.2.5. Purchaser will specify and identify the castings or forgings that will be inspected.

4.2.2.2 Radiography.

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

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

4.2.2.3 Ultrasonic Inspection.

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

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

4.2.2.4 Magnetic Particle Inspection.

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

4.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII., Division 1, Appendix 6 of the ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E-125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 3.

Table 3
Maximum Severity of Defects in Castings

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

4.2.2.5 Liquid Penetrant Inspection.

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

4.2.2.5.2 The acceptance standard used for welded fabrications shall be Section VIII., Division 1, Appendix 8 of the ASME Code. The acceptance standard used for castings shall be Section VIII., Division 1, Appendix 7 of the ASME Code.

Note: *Regardless of the generalized limits in 4.2.2, it shall be the packager's responsibility to review the design limits of the equipment in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 4.2.2 shall be removed to meet the quality standards cited, as determined by the inspection method specified.*

4.2.3 Mechanical Inspection.

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

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

• **4.2.3.3** When specified, the purchaser may inspect for cleanliness the equipment and all piping and appurtenances furnished by or through the packager before heads are welded to vessels, openings in vessels or exchangers are closed, or piping is finally assembled.

• **4.2.3.4** 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 zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the packager.

4.3 Testing.

4.3.1 General.

4.3.1.1 Equipment shall be tested in accordance with:

4.3.2 - Hydrostatic Test

4.3.3 - Gas Generator Test

4.3.4 - Complete Unit No-Load Mechanical Running Test

4.3.1.2 Optional tests may be specified by the purchaser as described in 4.3.5.

4.3.1.3 Refer to Figure 2, Testing Logic Diagram which shows the desired sequence of mandatory and optional operation testing.

4.3.2 Hydrostatic Test.

4.3.2.1 Pressure-containing parts, exclusive of gas turbine casing, shall be tested hydrostatically with liquid at a minimum of 1-1/2 times the maximum allowable working pressure but not less than 20 pounds per square inch gauge (1.4 bar gauge). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

• **4.3.2.2** When specified, the gas turbine casing(s) shall be tested to the criteria in 4.3.2.1.

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

4.3.2.4 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.

4.3.2.5 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

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

4.3.3 Gas Generator Test. The gas generator as a component or as a part of the assembled turbine shall be subjected to a mechanical running and performance test in accordance with the manufacturers standard and shall include as a minimum:

4.3.3.1 Each gas generator shall be subjected to a mechanical running and performance test conducted in the following sequence.

a. Operate gas generator from zero to idle speed and allow unit to stabilize.

b. Operate gas generator at speeds from idle to maximum continuous speed in speed increments allowing the unit to stabilize at each point and necessary mechanical and performance data be recorded. Increase speed to trip speed if achievable under ambient test conditions.

c. Reduce speed to idle, retracing the points in item 2 in descending order.

d. Caution should be exercised when operating at or near critical speeds.

4.3.3.2 The following basic requirements shall be met for the gas generator mechanical running and performance test.

a. A normal engine start.

b. Full range operation of variable inlet guide vanes and/or stator stages.

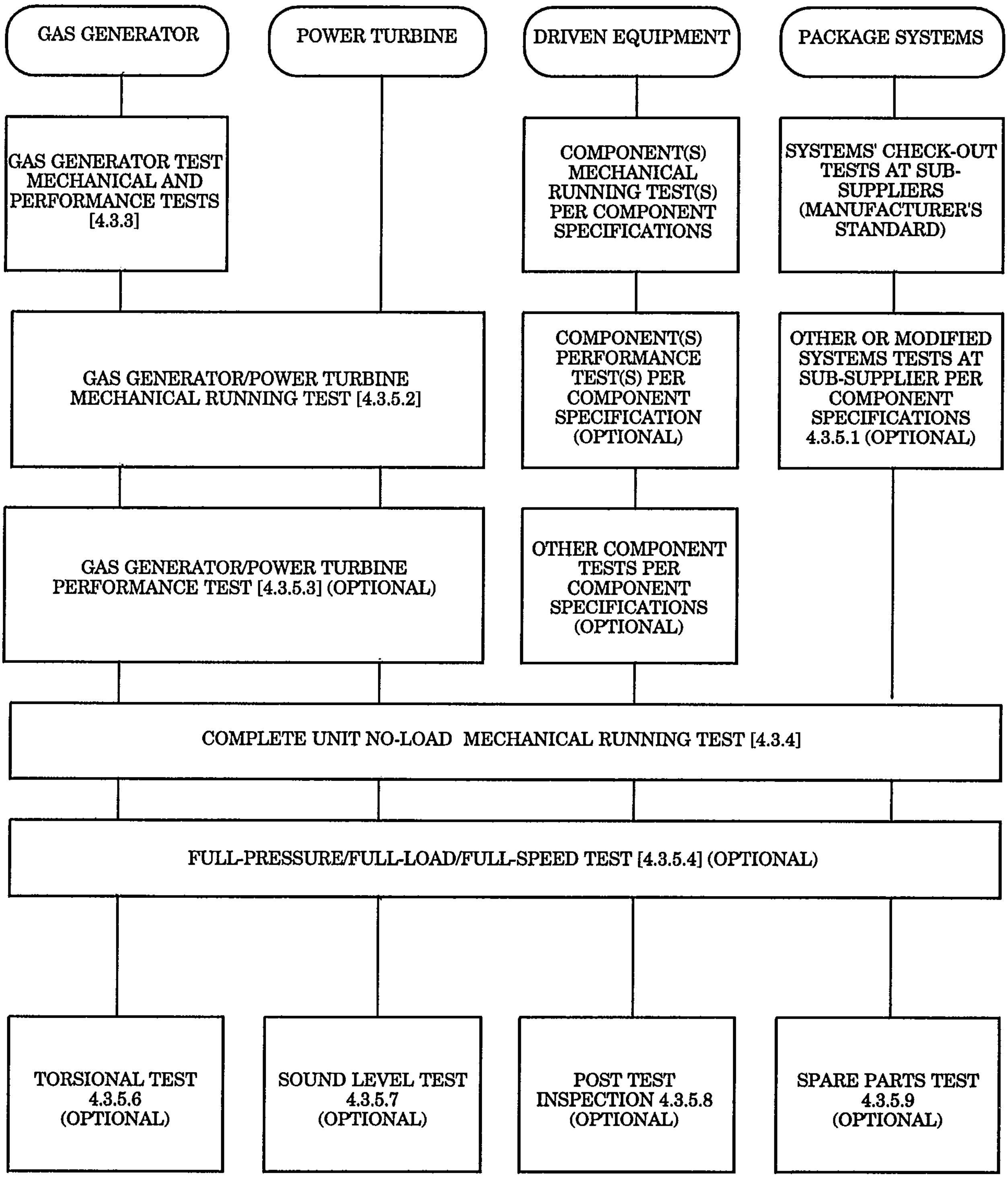


FIGURE 2
TESTING LOGIC DIAGRAM

c. Operation of bleed valves.
d. Operation of anti-icing systems (when they are furnished).
e. 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. Lubricant consumption shall be determined. Filters and any chip detectors shall be examined at the completion of testing.
f. The casings, lube oil system, fuel system and hydraulic system shall be checked for joint and connection tightness. All oil and fuel leaks shall be corrected. Air leaks adversely affecting performance and posing a safety hazard in the judgement of the purchaser shall be corrected.
g. All warning, protective and control devices shall be adjusted prior to the test and employed during the test when possible.

4.3.3.3 During the gas generator mechanical running and performance test, the mechanical operation of all equipment shall be satisfactory. Vibration readings shall not exceed the limit of paragraph 2.3.6 and/or 2.3.6.1. The performance of the machine shall meet the criteria specified.

4.3.4 Complete Unit No-load Mechanical Running Test.

4.3.4.1 Test preparation shall be in accordance with paragraphs 4.3.4.1.1 through 4.3.4.1.11 shall be performed before the Complete Unit No-Load Mechanical Running Test is performed.

4.3.4.1.1 The contract bearings and, where practical, the contract shaft seals shall be used in the package for the mechanical running test.

4.3.4.1.2 All lubricating oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the packager's operating instructions for the specific unit being tested. For pressure lubrication systems, oil flow rates to each oil film sleeve type bearing housing shall be determined.

4.3.4.1.3 Test-stand oil filtration 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.

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

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

4.3.4.1.6 For compressor applications, facilities shall be installed to prevent the entrance of oil or other debris into the compressor during the mechanical running test. These facilities shall be in operation throughout the test.

4.3.4.1.7 Testing with the contract coupling(s) is required. 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(s) have not moved on the shaft during the tests.

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

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

4.3.4.1.10 The vibration characteristics determined by the use of the instrumentation specified in 4.3.4.1.8 and 4.3.4.1.9 shall serve as the basis for acceptance or rejection of the package [2.3.6].

4.3.4.1.11 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 contract instrumentation during the test.

4.3.4.2 Speed Control.

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

4.3.4.2.2 The output speed shall be increased to one percent below trip speed and the equipment shall be run at this speed for a maximum of 15 minutes.

4.3.4.2.3 Overspeed trip devices shall be checked and adjusted until three consecutive trip values within 1 percent of the nominal trip setting are attained.

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

4.3.4.2.5 The speed shall be reduced to the maximum continuous speed, and the equipment shall be run for 4 hours.

NOTE: *Caution should be exercised when operating at or near critical speeds.*

4.3.4.3 Test Operation.

4.3.4.3.1 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 levels of each component shall not exceed the specified limits and shall be recorded throughout the operating speed range.

4.3.4.3.2 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 at 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 (1500 hertz). If the amplitude of any discrete, nonsynchronous vibration exceeds 20 percent of the specified vibration levels the purchaser and the packager shall mutually agree on requirements for any additional testing and on the equipment's suitability for shipment.

4.3.4.3.3 The mechanical running test shall verify that lateral critical speeds conform to the requirements of 2.4 and 2.5. For flexible-shaft machines, the first lateral critical speeds shall be determined during the mechanical running test and stamped on the nameplate followed by the word "test." When the first critical speed cannot be determined due to damping, the calculated critical speed shall be stamped on the nameplate followed by the word "calculated" [2.7].

● 4.3.4.3.4 When specified, tape recordings shall be made of all real-time vibration data.

4.3.4.4 Post Test Inspection.

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

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

4.3.5 Optional Tests. When specified, the optional shop tests described in 4.3.4.1 through 4.3.4.9 shall be performed.

● **4.3.5.1 Auxiliary Equipment Tests.** When specified, auxiliary equipment such as oil systems and control systems shall be tested prior to the No-load Complete Unit Mechanical Running Test. Details of the auxiliary equipment tests shall be developed jointly by the purchaser and the packager.

● **4.3.5.2 Gas Generator/Power Turbine Mechanical Running Test.** When specified, a separable gas generator and power turbine shall be mechanically run tested together. Testing shall be in accordance with paragraph 4.3.3. The mechanical condition of power turbines with hydrodynamic bearings shall comply with the vibration and balancing requirements of paragraph 2.3.6.

● **4.3.5.3 Gas Generator/Power Turbine Performance Running Test.** When specified, the gas turbine (gas generator and power turbine) shall be tested in accordance with ASME Power Test Codes 1 and 22 and as mutually developed by the purchaser and the packager.

● **4.3.5.4 Full-Pressure/Full-Load/Full-Speed Test.** When specified, the details of the full-pressure/full-load/full-speed test shall be developed jointly by the purchaser and the packager. This test may be substituted for the mechanical running test.

● **4.3.5.5 Electrical Generator Test.**

● 4.3.5.5.1 When specified, the electrical generator shall be tested at the generator Vendor's manufacturing facility in accordance with Appendix E, Inspections and Testing of Large Electric AC Generators.

● 4.3.5.5.2 When specified, the generator shall be load performance tested with the package coincidental with the turbine/load equipment train mechanical run test at packager's facility.

● **4.3.5.6 Torsional Test.** When specified, torsional vibration measurements shall be made to verify the package analysis.

● **4.3.5.7 Sound-Level Test.** The sound-level test shall be performed in accordance with ANSI S5.1, as specified by the purchaser.

● **4.3.5.8 Post-Test Inspection.** Dismantling, inspection and reassembly of the major driven equipment, gear and the driver shall be made after satisfactory completion of the mechanical running test. Packager and purchaser shall agree to what extent the package equipment shall be dismantled. Some aircraft-derivative turbine designs are impracticable for dismantling type inspections.

● **4.3.5.9 Spare-Parts Test.** Spare parts such as rotors and gears shall be tested as specified by the purchaser.

4.4. Preparation for Shipment.

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

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

4.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been approved by the purchaser. Preparation shall be in accordance with paragraphs 4.4.3.1 through 4.4.3.11.

4.4.3.1 Unless otherwise specified, exterior surfaces, except for machined surfaces, shall be painted with a prime coat and at least one finish coat.

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

4.4.3.3 The interior of the rotating equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a suitable rust preventative that can be removed with solvent.

4.4.3.4 Internal steel areas of bearing housings and carbon steel oil systems' auxiliary equipment such as reservoirs, vessels, and piping shall be coated with a suitable oil-soluble rust preventative.

4.4.3.5 Flanged openings shall be provided with metal closures at least 3/16 inch (4.8 millimeters) thick, with rubber gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures.

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

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

4.4.3.8 Lifting points and lifting lugs shall be clearly identified.

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

● **4.4.3.10** When a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 3 years. The rotor shall be treated with a rust preventative and shall be housed in a vapor-barrier envelope with a slow-release vapor-phase inhibitor. The rotor shall be suitably crated for domestic or export shipment, as specified. Suitable sheeting, at least 1/8 inch (3.2 millimeters) thick, shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

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

4.4.4 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the packagers connection table or general arrangement drawing, service and connection designations shall be indicated.

4.4.5 Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapor-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags 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 by corrosion-resistant tags attached with stainless steel wire.

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

SECTION 5
PACKAGER'S DATA

5.1 Proposals.

5.1.1 General. The packager shall forward the original and the specified number of copies of the proposal to the addressee stated on the inquiry documents. This proposal shall contain, as a minimum, the data specified in 5.1.2 through 5.1.4, and a specific statement of compliance with the purchaser's inquiry specifications, and a detailed list of any exceptions specifically identified as such. The packager shall provide details to evaluate any alternative designs proposed. All correspondence shall be clearly identified.

5.1.2 The packager shall complete and forward the Packager Drawing and Data Requirements form [Appendix B] to the address(s) 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.

5.1.3 Coordination Meeting. A coordination meeting shall be held, preferably at the packager's plant, within 4-6 weeks after the purchase commitment. The purchaser will propose an agenda prior to this meeting which, typically includes:

a. The purchase order, scope of supply, and subvendor items.

b. The preliminary data sheets.

c. Applicable specifications and previously agreed upon exceptions.

d. Schedules.

e. Testing program.

f. Main component general arrangement.

g. Project administration requirements.

h. Any startup, shutdown, or operating restrictions required to protect the integrity of the equipment shall be stated [2.1.9.5].

● **5.1.4 Curves.** The proposal shall contain a power output versus speed curve for rated site conditions. It should follow the format shown in Appendix B. Additional curves shall be presented for conditions of specified maximum and minimum site ambient temperature. Curves should also show any limit condition of driven load, such as the compressor surge line. All curves shall include power deductions (or fuel increases) for inlet and exhaust pressure losses to reflect inlet/exhaust equipment specified or proposed. When specified, the curves described below shall also be furnished.

5.1.4.1 Speed/torque curve for 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.

5.1.4.2 Incremental power output for increments of steam or water injection. The purchaser shall state the quantity and condition of injection steam available.

5.1.4.3 For turbine/generator units, performance curves shall also include kilowatt output versus gas turbine ambient inlet temperature and generator power (KW) capability versus ambient or cooling fluid temperatures.

5.1.4.4 Gas turbine exhaust emissions.

5.1.5 Technical Requirement. As a minimum, the packager shall provide the following additional items in the proposal:

— Maintenance and inspection requirements (2.1.7).

— Spare parts listings (2.1.8).

— Expected emission levels (2.1.11).

— Packaged equipment (2.2.1 and 2.2.2).

— Other equipment (2.2.3).

— Starting restrictions (2.2.9).

— Special tools and fixtures (2.2.16.1).

— Lube oil and seal oil systems (2.3.5.2.2).

— Materials identification (2.6.1.2).

— Filter performance (3.4.2.2).

— Water wash requirements (3.7.1 and 3.7.4).

● — Deviations from API 614 requirements (3.7.1 and 3.7.4).

— Fuel gas requirements (3.8.2.1 and 3.8.2.3.2).

— Dual fuel system (3.8.4.5).

— Water/steam injection system (3.8.5.3).

— Control system (3.9.1.5 and 3.9.2.4).

5.2 Contract Data.

5.2.1 General.

5.2.1.1 The contract information to be furnished by the packager is specified in Appendix B. Each drawing, bill of material, or data sheet shall have a title block in the lower right hand corner with date of certification, revision number, date, and title.

5.2.1.2 The Packager Drawing and Data Requirement sheet shall indicate which, if any, data must be reviewed before components on that drawing can be released for purchase or manufacture.

5.2.1.3 The purchaser will return data submitted for review within two weeks after receipt, with any comments identified in the two categories listed below.

a. Information on accessory items that are included in the order specifications, but not on the data issued.

b. Items which are not included in the order specifications in effect at the time of drawing issue, but which the purchaser has requested via amended specifications.

Within two weeks of receipt of the marked up data, the packager shall issue revised data incorporating all comments and any other specified details not included in the first issue. The purchaser will review data and return with any further comments. This cycle will be repeated until the Packager receives a review issue with no comments, at which time a certified issue shall be made and stamped "final".

5.2.1.4 Return without comment does not constitute permission from purchaser for the packager to deviate from any requirements of the order, unless specifically agreed to in writing by a change of the purchase specifications.

5.2.1.5 A complete list of all packager data shall be included with the first issue of major drawings. This list will contain titles, drawing numbers, and a schedule for transmission of all data the packager will furnish.

5.2.2 Drawings. The drawing(s) furnished shall contain sufficient information so that when combined with the manuals covered in 5.2.5, the purchaser may properly install, operate, and maintain the ordered equipment. Drawings shall be clearly legible, and be in accordance with ANSI Y14.2M. Details listed in Appendix B shall be provided as a minimum.

5.2.3 Technical Data. Data shall be submitted, per Appendix B. Any drawing comments or specification revisions necessitating a change in the data shall be noted by the packager and will result in reissue of the completed, corrected data sheets by the purchaser as part of the order specifications.

5.2.4 Recommended Spares. The packager shall submit a supplementary list of spare parts other than those included in his original proposal. This supplementary list shall include recommended spare parts for all equipment supplied, with cross-sectional or assembly type drawings, part numbers, and delivery times. Part numbers shall identify each part for interchangeability purposes. Standard purchased items shall be identified by the original manufacturer's numbers. The packager shall forward this supplementary list to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field startup.

5.2.5 Installation, Operation, and Maintenance Manuals.

5.2.5.1 The packager shall provide sufficient written instructions and a cross-referenced list of all drawings to enable the purchaser to correctly install, operate, and maintain the complete equipment ordered. This information shall be compiled in a manual (or manuals) with an index sheet containing section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared specifically for this installation and shall not by "typical."

5.2.5.2 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 operating and maintenance instructions. This manual shall be forwarded at a time mutually agreed upon in the order, but not later than the final issue of prints. The manual shall contain information such as special alignment or grouting procedures, utility specifications (including quantity), and all installation design data including any pertinent drawings/data specified in 5.2.2 and 5.2.3. Unless otherwise included, sketches showing the location of center of gravity and rigging provisions to permit removal of the top half of the casing, the rotor, and any subassemblies that weigh more than 300 pounds (136 kilograms) shall be furnished.

5.2.5.3 Operating and Maintenance Manual. The manual containing operating and maintenance data shall be forwarded no later than six weeks after the successful completion of all specified tests. The manual shall include a section to cover special instructions for operations at specified extreme environmental conditions, such as temperatures. In addition, as a minimum, it shall include:

a. As built data sheets.

b. Certified site performance curves.

c. All contract drawings.

d. As built assembly clearances.

e. An itemized parts list for all equipment supplied. The list shall completely identify each part so that the purchaser may determine the part's interchangeability with other equipment furnished by the same packager. Standard purchased items shall be identified by the original manufacturer's numbers.

● **5.2.6 Technical Data Manual.** The packager shall make the following information available for review by the purchaser within thirty days of package shipment. Reports shall be identified with a title page and shall contain copies of raw shop data (with specified witness signature) along with sample calculations (if applicable) and tabulation of the final test results.

a. The packager's physical and chemical data from mill reports (or certification) of critical alloy or steel pressure parts and forgings [2.6.1.2].

b. Certified shop logs of all tests [4.3].

c. When specified, tape recordings of real-time vibration data.

d. Technical analyses data/lateral, torsional, and Campbell diagrams as required [2.4, 2.5].

APPENDIX A
TYPICAL DATA SHEETS

APPLICABLE SPECIFICATIONS AND DATA SHEETS

THE LATEST REVISION OF THE FOLLOWING DOCUMENTS SHALL BECOME A PART OF THIS RECOMMENDED PRACTICE

REFERENCE	SPECIFICATION	DATA SHEET
API 11P - Packaged Reciprocating Compressors	☐	☐
API 610 - Centrifugal Pumps	☐	☐
API 611 - General Purpose Steam Turbines	☐	☐
API 613 - Special Purpose Gear Units	☐	☐
API 614 - Oil Systems	☐	☐
API 616 - Gas Turbines	(Section 2 only) ☐	☐
API 617 - Centrifugal Compressors	☐	☐
API 618 - Reciprocating Compressors	☐	☐
API 660 - Shell & Tube Heat Exchangers	☐	☐
API 661 - Air Cooled Heat Exchangers	☐	☐
API 670 - Vibration, Bearing, & Temperature Monitors	☐	☐
API 671 - Couplings	☐	☐
API 678 - Accelerometer Based Vibration Monitors	☐	☐
ANSI C50.12 - Salient Pole Generator	☐	☐
Manufacturer Standard	☐	☐
______	☐	☐
______	☐	☐
Purchaser Specification [2.2.5]	☐	☐
Noise Specifications [2.1.10]	☐	☐
Emission Specifications [2.1.11]	☐	☐
Third Party Certification	☐	☐
Other	☐	☐

OTHER APPLICABLE REFERENCE DRAWINGS:

- EQUIPMENT PLOT/GENERAL ARRANGEMENT PLAN, DRAWING NUMBER ______ ☐
- PROCESS SYSTEM DIAGRAM, DRAWING NUMBER ______ ☐
- GENERATOR POWER SYSTEM ONE LINE DIAGRAM, DRAWING NUMBER ______ ☐
- OTHER, DRAWING NUMBER ______ ☐

API SPECIFICATION 11 PGT-PACKAGED GAS TURBINES
PRIME MOVER EQUIPMENT DATA SHEETS

PAGE 1 OF 10
JOB NO. ____ ITEM ____
P.O. NO. ____ DATE ____
INQUIRY NO. ____ BY ____
REVISION ____ DATE ____

GENERAL

APPLICABLE TO: O PROPOSAL O PURCHASE O AS BUILT

O FOR ____ O UNIT ____
O SITE ____ ☐ SERIAL NO. ____
O SERVICE ____ O NO. REQUIRED ____
O GEOGRAPHIC LOCATION ____ O UBC SEISMIC ZONE (2.1.9.1) ____
O PACKAGER ____ ☐ MODEL ____ ☐ SHOP ORDER ____
☐ DRIVER MANUFACTURER ____ ☐ MODEL ____ ☐ SERIAL NO. ____
☐ DRIVEN EQUIPMENT TYPE ____ ☐ MANUFACTURER ____ ☐ MODEL ____ ☐ SERIAL NO. ____
☐ ADDITIONAL DRIVEN EQUIPMENT TYPE ____ ☐ MANUFACTURER ____ ☐ MODEL ____ ☐ SERIAL NO. ____
TYPE ____ ☐ MANUFACTURER ____ ☐ MODEL ____ ☐ SERIAL NO. ____
O OUTPUT REQUIRED ____
O OPERATING SPEED RANGE REQUIRED ____ CYCLE: O REGEN O SIMPLE O EXHAUST HEAT RECOVERY
TYPE OF GAS TURBINE: ■ SINGLE SHAFT ■ MULTI SHAFT
DUTY: O CONTINUOUS O INTERMITTENT O STANDBY
OPERATION (2.1.9.4) O ATTENDED O UNATTENDED

NOTE: INFORMATION TO BE COMPLETED: O BY PURCHASER ☐ BY PACKAGER ■ BY PACKAGER IF NOT BY PURCHASER

PERFORMANCE

I. GAS TURBINE, INCLUDING ALL ENGINE DRIVEN PARASITIC LOSSES

TEMP	SITE RATED	NORMAL DUTY	SITE MAX TEMP	SITE MIN
O DRY BULB TEMP. °F	____	____	____	____
O RELATIVE HUMIDITY %	____	____	____	____
O BAROMETER PSIA	____	____	____	____
☐ OUTPUT, KW (HP) (1)	____	____	____	____
☐ HEAT RATE, LHV BTU/KW(HP)-HR	____	____	____	____
■ OUTPUT SHAFT SPEED, RPM	____	____	____	____
☐ INLET AIR FLOW LBS/SEC	____	____	____	____
☐ INLET AIR SYSTEM ΔP, IN. H20	____	____	____	____
☐ FIRING TEMP. °F	____	____	____	____
☐ EXHAUST FLOW LBS/SEC (1)	____	____	____	____
☐ EXHAUST SYSTEM ΔP, IN. H20	____	____	____	____
☐ EXHAUST TEMP., °F	____	____	____	____

(1) INCLUDING EFFECTS FOR O STEAM O WATER INJECTION
O DRIVEN EQUIPMENT, SEE SEPARATE DATA SHEETS (XXXX)

■ EMISSION CONTROL ■ AUGMENTATION

☐ STEAM FLOW, LB/HR	____	____	____	____
☐ WATER FLOW, GPM	____	____	____	____

LOCATION (2.1.9.1)

O GEOGRAPHIC LOCATION ____
O U.B.C. SEISMIC ZONE ____

O INDOOR O OUTDOOR
O HEATED O UNDER ROOF
O UNHEATED O PARTIAL SIDES

O ELEC. AREA CLASSIFICATION (2.1.9.2, 2.2.5)

	NON-HAZARDOUS	CL/GRP/DIV
GAS TURBINE AREA	O	/ /
GAS TURBINE ENCLOSURE	O	/ /
CONTROL PANEL	O	/ /

O MARINIZATION REQUIRED ☐ WINTERIZATION REQUIRED
O TROPICALIZATION REQUIRED (3.10.6)
UNUSUAL CONDITIONS: O DUST O FUMES
O OTHER (2.1.9.1) ____

PACKAGE SOUND LEVEL (2.1.10):

O NEAR FIELD ____ dbA @ 3 FEET
O FAR FIELD (3.3.1.2) ____ DBa @ ____ FEET

SHIPMENT REQUIREMENTS

O WEIGHT/DIMENSIONAL LIMITATIONS ____
O SPECIAL CONSIDERATIONS ____
O DOMESTIC O EXPORT O EXPORT BOXING REQUIRED
O OUTDOOR STORAGE MORE THAN 6 MONTHS
O OCEAN TRANSPORT PREPARATION TYPE ____
O LIFT SLINGS/SPREADERS BY PACKAGER ____

PAINTING

O MANUFACTURER'S STD.
O OTHER ____

API SPECIFICATION 11 PGT-PACKAGED GAS TURBINES
PRIME MOVER EQUIPMENT DATA SHEETS

PAGE 2 OF 10
JOB NO. ____ ITEM ____
P.O. NO. ____ DATE ____
INQUIRY NO. ____ BY ____
REVISION ____ DATE ____

UTILITIES AND CONNECTIONS (2.2.8.2)

○ UTILITY CONDITIONS

STEAM: AUX DRIVERS / HEATING

	AUX DRIVERS		HEATING	
INLET MIN	PSIG	°F	PSIG	°F
NORM	PSIG	°F	PSIG	°F
MAX	PSIG	°F	PSIG	°F
EXHAUST MIN	PSIG	°F	PSIG	°F
NORM	PSIG	°F	PSIG	°F
MAX	PSIG	°F	PSIG	°F
	STARTING		INJECTION	
INLET MIN	PSIG	°F	PSIG	°F
NORM	PSIG	°F	PSIG	°F
MAX	PSIG	°F	PSIG	°F
EXHAUST MIN	PSIG	°F		
NORM	PSIG	°F		
MAX	PSIG	°F		

☐ TOTAL UTILITY CONSUMPTION:

COOLING WATER ____ GPM
STEAM LEVEL ____ PSIG ____ PSIG ____ PSIG
STEAM, NORMAL ____ ____ ____ PSIG
STEAM, MAX ____ ____ ____ PSIG
INSTRUMENT AIR ____ SCFM
MOTORS (AUXILIARIES) ____ KW
BATTERY CHARGERS ____ KW
HEATERS ____ KW
PURGE (AIR OR N_2) ____ SCFM

ELECTRICITY (3.10.1):

	MOTORS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

COOLING WATER:

TEMP. INLET ____ °F MAX RETURN ____ °F
PRESS NORM ____ PSIG DESIGN ____ °F
MIN RETURN ____ PSIG MAX ALLOW ΔP ____ PSID
DESIGN ____
WATER SOURCE ____

INSTRUMENT AIR PRESSURE, PSIG:

MAX ____ NORMAL ____ MIN ____

TURBINE AIR EXTRACTION REQUIRED:

○ SCFM ____ @
☐ MAXIMUM PRESSURE AVAILABLE
PSIG ____ @ ____
☐ DISCHARGE TEMP ____ °F
☐ COMPRESSOR STAGE EXTRACTED ____
NOTES: ____

PURCHASER CONNECTIONS

CONNECTION	☐ SIZE	☐ FACING & RATING	○ POSITION	■ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY FT/SEC
INLET AIR						
EXHAUST GAS						
GAS FUEL SUPPLY						
STARTING AIR SUPPLY						
NOX SUPPRESSION WATER						
COOLING WATER						
NOX SUPPRESSION STEAM						
STARTING STEAM SUPPLY						

NOTES: ____

API SPECIFICATION 11 PGT-PACKAGED GAS TURBINES PRIME MOVER EQUIPMENT DATA SHEETS	PAGE 3 OF 10 JOB NO.___ ITEM___ P.O. NO.___ DATE___ INQUIRY NO.___ BY___ REVISION___ DATE___	
APPLICABLE SPECIFICATIONS, DATA SHEETS AND DRAWINGS (2.3)		
REFERENCE	SPECIFICATION	DATA SHEET
API 11P - PACKAGED RECIPROCATING COMPRESSORS	O	O
API 610 - CENTRIFUGAL PUMPS	O	O
API 611 - GENERAL PURPOSE STEAM TURBINES	O	O
API 613 - SPECIAL PURPOSE GEAR UNITS	O	O
API 614 - OIL SYSTEMS	O	O
API 616 - GAS TURBINES - SECTION 2 ONLY	O	O
API 617 - CENTRIFUGAL COMPRESSORS	O	O
API 618 - RECIPROCATING COMPRESSORS	O	O
API 660 - SHELL & TUBE HEAT EXCHANGERS	O	O
API 661 - AIR COOLED HEAT EXCHANGERS	O	O
API 670 - VIBRATION, BEARING, & TEMPERATURE MONITORS	O	O
API 671 - COUPLINGS	O	O
API 678 - ACCELEROMETER BASED VIBRATION MONITORS	O	O
ANSI C50.12 - SALIENT POLE GENERATOR	O	O
ANSI C50.14 - CYLINDRICAL POLE GENERATOR	O	O
APPENDIX E - ELECTRIC AC GENERATOR 92.3.5.4.1)	O	O
PURCHASER CODE REQUIREMENTS (1.5.1)	O	O
OTHER (1.5.1)	O	O
THIRD PARTY CERTIFICATION (1.5.2)	O	O
EMISSION SPECIFICATIONS (2.1.11)	O	O
MANUFACTURER STANDARDS (2.3)	O	O

APPLICABLE REFERENCE DRAWINGS:

O EQUIPMENT PLOT/GENERAL ARRANGEMENT PLAN, DRAWING NUMBER__________

O PROCESS SYSTEM DIAGRAM, DRAWING NUMBER__________

O GENERATOR POWER SYSTEM ONE LINE DIAGRAM, DRAWING NUMBER__________

O OTHER, DRAWING NUMBER__________

NOTES:__________

API SPECIFICATION 11 PGT-PACKAGED GAS TURBINES
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ACCESSORY SYSTEMS SUPPLIED BY PACKAGER (SPEC. 3)

STARTING SYSTEM (3.1)

TYPE (3.1.1) O MOTOR O TURBINE
O GAS EXPANDER O ICE ENGINE O HYDRAULIC
O GAS TURBINE ■ STARTER IS CLUTCHED (3.1.6)
☐ STARTER RATING (3.1.2)____HP
☐ SHAFT TURNING DEVICE REQUIRED____

☐ MOTOR (3.1.4):

TYPE____ RATING____HP
MFR.____ MODEL____HP

☐ STEAM TURBINE (3.1.4):

MFR.____ MODEL____

HP____MAX STEAM FLOW____LBS/HR
TOTAL/START____LBS

O GAS EXPANDER (3.1.5)

APPLICABLE SPEC.____

MFR.____ MODEL____

HP____MAX GAS FLOW____LBS/HR
TOTAL/START____LBS

O GAS FOR EXPANSION TURBINE:____

	MIN	MAX	NORMAL
INLET PRESSURE, PSI	____	____	____
EXHAUST PRESS, PSI	____	____	____
GAS TEMP., °F INLET	____	____	____
GAS TEMP., °F EXHAUST	____	____	____
MOLECULAR WEIGHT	____	____	____

SPEED CONTROL: O GOVERNOR O 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____PSI
CASING MATERIAL____
SEAL TYPE____
☐ IC ENGINE

TYPE O SPARK IGNITED O DIESEL
APPLICABLE SPEC____
MFR____ MODEL____
HP____ RPM____
☐ GAS TURBINE
APPLICABLE SPEC____
MFR____ MODEL____
HP____ RPM____

MOUNTING SYSTEMS (3.2)

O TYPE OF FOUNDATION (3.2.1.1)____
O SUITABLE FOR EPOXY GROUT (3.2.2.2)____
O BASEPLATE (3.2.3.1), SINGLE____ MULTIPLE____
O LEVELING PADS/TARGETS (3.2.3.2)____
O COLUMN MOUNTING (3.2.3.3) O THERMAL ISOLATION
O EXTERNAL EXCITING FORCES (2.4.2.2)____
____
O SUPPORT SYSTEM VALUE (2.5.2.2.A)____
____
O DECKING/GRATING, TYPE (3.2.3.6)____
____

ENCLOSURE AND FIRE PROTECTION (3.3)

O ENCLOSURE TYPE____
O FIRE SUPPRESSION BY CO_2
O FIRE SUPPRESSION BY HALON 1301
O SPECIAL DESIGN CONSIDERATIONS____
____
O VENTILATION FAN REDUNDANCY (3.3.4.1)
O POSITIVE PRESSURE VENTILATION (3.3.4.1)
O EXTERNAL DUCTING BY PURCHASER (3.3.4.4)
☐ D.C. FAN REQUIRED____HP

OTHER:____

COUPLINGS AND GUARDS (2.3.2)

O SEE ATTACHED API-671 DATA SHEETS
☐ MANUFACTURER____ ☐ TYPE____
☐ MODEL____ ☐ GUARD SUPPLIED BY____
☐ MAX O.D.____IN
☐ HUB WEIGHT____LBS
☐ SPACER LENGTH____IN
☐ SPACER WEIGHT____LBS
O IDLING ADAPTER REQUIRED

LUBRICATION REQUIREMENTS:

O NON-LUBE O GREASE O CONT. OIL LUBE
QUANTITY PER HUB____LBS OR GPM

NOTES:____

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ACCESSORY SYSTEMS SUPPLIED BY PACKAGER (SPEC. 3) - CONTINUED

AIR INLET SYSTEM (3.4)

☐ AIR FILTER MFR_____ MODEL_____
○ TYPE_____
○ AIR PATH COMPONENT MATERIAL (3.4.1.7)_____
LOCATION: ○ GROUND LEVEL ○ ELEVATED
○ PROVISIONS FOR EXTRA STAGES
○ DESIGN WIND VELOCITY_____MPH
○ NORMAL DUST LOADING_____LB/SCFM
☐ FILTRATION EFFICIENCY (3.4.2.2)_____
☐ MAINTENANCE INTERVAL (3.4.2.2)_____MONTHS
☐ CLEANING FREQUENCY (3.4.2.2)_____DAYS
☐ AIR FILTER ΔP, IN H20, @ 100% RATED AIR FLOW (3.4.2.2)
_____CLEAN, _____ALARM, _____SHUTDOWN
☐ ΔP INDICATOR MFR_____ MODEL_____
○ SILENCER, TYPE (3.4.3)
☐ SILENCER, MFR_____ MODEL_____
☐ SILENCER ΔP, IN H20, @ 110% RATED AIR FLOW_____
☐ DUCTING GAGE/MATERIAL (3.4.1)_____
☐ EXP JOINT MFR_____ TYPE_____
☐ OFF-LINE WASH SYSTEM, TYPE (3.4.1.1)_____
○ ON-LINE WASH SYSTEM, TYPE (3.4.1.2)_____
○ EVAPORATIVE COOLER (3.4.5) ☐ EFFICIENCY (3.4.5.2)_____
☐ EVAPORATIVE COOLER MFR_____ MODEL_____
☐ EVAPORATIVE COOLER ΔP, IN H20 @ 110% RATED AIR FLOW
○ ANTI-ICING, TYPE (3.4.7.1)_____ ☐
COMPLETE AIR INLET SYSTEM ΔP, IN H20
@ 110% RATED AIR FLOW (3.4.1.3)_____
OTHER:_____

EXHAUST SYSTEM (3.5)

○ COMPLETE EXHAUST SYSTEM REQUIRED (3.5.1)
☐ EXPANSION JOINT MFR_____ TYPE_____
☐ SILENCER MFR_____ ΔP_____IN.H20
☐ DUCTING GAGE/MATERIAL (3.5.4)_____
○ PERSONNEL PROTECTION INSULATION (3.5.2.A)_____
DISCHARGE FLANGE ORIENTATION (3.5.2.B):
○ VERTICAL ○ HORIZONTAL
○ EXTERNAL ΔP BY OTHERS_____IN H10, MAX
○ HEAT RECOVERY DEVICE
☐ MFR_____ TYPE_____ ΔP_____IN H20
☐ STEAM GEN: PRESS_____ PSIG TEMP_____°F
RATE_____LBS/HR
☐ COMPLETE EXHAUST SYSTEM SITE RATED ΔP_____IN.H20

EMISSIONS (2.1.11)

○ NOx REQUIREMENTS_____
☐ NOx EMITTED_____
EMISSIONS REDUCTION METHOD (IF REQUIRED)
■ WATER INJECTION ■ SCR
■ STEAM ■ DRY COMBUSTOR
■ OTHER_____
○ SO_x REQUIREMENTS_____
○ SULFUR CONTENT OF FUEL_____
☐ SO_x EMITTED (BASED ON STATED SULFUR CONTENT)_____
○ CO REQUIREMENTS_____
☐ CO EMITTED_____
○ PARTICULATE REQUIREMENTS_____
☐ PARTICULATE EMITTED_____
○ UNBURNED HC REQUIREMENTS_____
OHTER:_____

OIL SYSTEMS (3.7)

☐ SEE ATTACHED API 614 DATA SHEETS
○ LUBE OIL VISCOSITY (3.7.6)_____ISO GRADE_____
☐ SYSTEM FOR SYNTHETIC LUBRICANT (3.6.2)_____
☐ LUBE SPECIFICATION_____

APPLICABLE EMISSION CODES OR REGULATIONS

○ EPA - TITLE 40 - CFR
○ OTHER:_____

NOTES:_____

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FUEL SYSTEM (3.8)

TYPE OF FUEL SYSTEM: O GAS O LIQUID O DUAL (GAS/GAS) O DUAL (GAS/LIQUID) O DUAL (LIQUID/LIQUID)
DUAL FUEL SYSTEM REQUIREMENTS (3.8.4):
O SHUTDOWN TO TRANSFER O TRANSFER @ (RATED) (___T RATED) LOAD
O (MANUAL) (AUTO) TRANSFER UNDER LOAD O MAX TIME ALLOWED TO COMPLETE TRANSFER ___SEC.

GAS FUEL (3.8.2)

O FUEL ANALYSIS - MOL % (3.8.1.2)

COMPOSITION:	M.W.	NORMAL	STARTING	ALT
AIR	29			
OXYGEN	32			
NITROGEN	38			
WATER VAPOR	18			
CARBON MONOXIDE	28			
CARBON DIOXIDE	44			
HYDROGEN	2			
METHANE	16			
ETHYLENE	26			
ETHANE	30			
PROPYLENE	42			
PROPANE	44			
I-BUTANE	58			
A-BUTANE	58			
I-PENTANE	72			
A-PENTANE	72			
HEXANE PLUS	_			
____	_			
TOTAL				

AVG. MOL WT.			
CORROSIVE AGENTS PPM			
CONTAMINANTS PPM			
LHV BTU/SCF (3.8.2.2)			
FUEL PRESS. MAX/MIN PSIG	/	/	/
FUEL TEMP MAX/MIN °F	/	/	/
☐ FUEL PRESS. REQUIRED MAX/MIN PSIG	/	/	/

O FUEL GAS COMPRESSION SYSTEM BY PACKAGER (3.8.2.3.2)

LIQUID FUEL (3.8.3)

O FUEL GRADE (3.8.1.2)____

LIQUID FUEL TREATMENT REQUIRED (3.8.3.2) O YES O NO
TREATMENT SYSTEM SUPPLIED BY O VENDOR O OTHER
HEATER REQUIRED ☐ YES ☐ NO
☐ LIQUID FUEL PRESS REQUIRED, MAX/MIN, PSIG _/_

FUEL ANALYSIS DATA

MEASURED PROPERTY	ASTM METHOD	VALUE
VISCOSITY SSU, 100°F		
DISTILLATION DATA:		
50% RECOVERY, °F MAX		
END POINT, °F MAX		
SULFUR CONTENT % WT.MAX		
LHV. BTU/LB		
CARBON RESIDUE (ON 10% BOTTOMS)		
COOPER STRIP CORROSION PLATE 3 HRS AT 212°F MAX		
AROMATIC CONTENT		
ASH CONTENT		
SPECIFIC GRAVITY 60°F		
FLASH POINT °F		
POUR POINT °F		
WATER		
FILTERABLE DIRT. MG/100ML		
TRACE METALS		
SODIUM		
POTASSIUM		
VANADIUM		
CALCIUM		
LEAD		
OTHER METALS		
____		

OTHER:____

WATER/STEAM INJECTION (3.8.5)

☐ WATER PRESSURE REQUIRED____
☐ STEAM PRESSURE REQUIRED____
☐ STEAM TEMPERATURE REQUIRED____
☐ WATER/STEAM QUALITY____

FUEL SYSTEM PIPING (3.8.1.4)

O BY PASS CONTROL VALVE ☐ ISOLATION BLOCK VALVES ■ ANSI FLANGE RATING____
☐ Y STRAINER____MESH ☐ BLOW DOWN OR VENT VALVE O OTHER____
O FINAL FILTER____MICRON O NACE MATERIAL STANDARDS

NOTES:____

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CONTROLS AND INSTRUMENTATION (3.9)

UNIT CONTROL PANEL POWER (3.1.0.2) O AC O DC

O PROCESS CONTROL SIGNAL INPUT (3.9.1.2.1)____________

O TIME FOR AC POWER OUTAGE RIDE THROUGH (3.9.1.3)____________

O FAULT TOLERANT DESIGN (3.9.1.4)____________

O BLACKSTART CAPABILITY (3.9.2.3)____________

☐ BLACKSTART TYPE (3.9.2.3)____________

UNIT CONTROL PANEL LOCATION (3.9.3.1)

O LOCAL O REMOTE

VIBRATION MONITOR (3.9.4.3) O API 670 O API 678

CONTROL, INSTRUMENT AND ALARM LIST (3.9.3.2)

⊙ INDICATES THAT THE SPECIFICATION DEFINES A MANDATORY REQUIREMENT

DESCRIPTION	OPT.	IND.	CONT.	AL.	SD.	LOC.	REM.
1. START SELECTOR, LOC/REM	O	O	⊙	O	O	O	⊙
2. START SEQUENCE, ENABLE	⊙	⊙	⊙	O	O	O	⊙
3. STOP SEQUENCE, ENABLE	⊙	O	⊙	O	O	O	⊙
4. EMERGENCY SHUTDOWN	⊙	O	⊙	⊙	⊙	O	⊙
5. FAIL TO CRANK	⊙	O	O	⊙	⊙	O	⊙
6. FAIL TO START	⊙	O	O	⊙	⊙	O	⊙
7. FAIL TO IGNITE	⊙	O	O	⊙	⊙	O	⊙
8. READY TO LOAD	⊙	⊙	O	O	O	O	⊙
9. HOUR METER	⊙	⊙	O	O	O	O	⊙
10. FIRED START COUNTER	⊙	⊙	O	O	O	O	⊙
11. START ATTEMPT COUNTER	O	⊙	O	O	O	O	⊙
12. SPEED SELECTOR, AUTO/MANUAL	⊙	O	⊙	O	O	O	⊙
13. SPEED, G.G.	⊙	⊙	O	O	O	O	⊙
14. SPEED, P.T.	⊙	⊙	O	O	O	O	⊙
15. SPEED, RAISE/LOWER	⊙	O	⊙	O	O	O	⊙
16. SPEED, SET POINT	⊙	⊙	O	O	O	O	⊙
17. UNDERSPEED, G.G.	O	O	O	⊙	⊙	O	⊙

NOTES:____________

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CONTROL, INSTRUMENT AND ALARM LIST (3.9.3.2) - CONTINUED

DESCRIPTION	OPT.	IND.	CONT.	AL.	SD.	LOC.	REM.
18. UNDERSPEED, P.T.	O	O	O	⊙	⊙	O	⊙
19. OVERSPEED, STARTER	O	O	O	⊙	⊙	O	⊙
20. OVERSPEED, G.G.	⊙	O	O	⊙	⊙	O	⊙
21. OVERSPEED, P.T.	⊙	O	O	⊙	⊙	O	⊙
22. OVERSPEED, BACKUP	O	O	O	⊙	⊙	O	⊙
23. FIRING TEMPERATURE, G.T.	⊙	⊙	O	⊙	⊙	O	⊙
24. GOVERNOR FAILURE	⊙	O	O	⊙	⊙	O	⊙
25. VIBRATION, G.G.	⊙	⊙	O	⊙	⊙	O	⊙
26. VIBRATION, P.T.	⊙	⊙	O	⊙	⊙	O	⊙
27. VIBRATION MONITOR FAILURE	⊙	O	O	⊙	⊙	O	⊙
28. BEARING TEMPERATURE	⊙	⊙	O	⊙	⊙	O	⊙
29. FUEL SUPPLY PRESSURE	⊙	⊙	O	O	O	⊙	⊙
30. FUEL PRESSURE, LO	⊙	O	O	⊙	⊙	O	⊙
31. FUEL PRESSURE, HI	⊙	O	O	⊙	⊙	O	⊙
32. FUEL SUPPLY TEMPERATURE	⊙	⊙	O	⊙	⊙	O	⊙
33. FUEL VALVE FAILURE	O	O	O	⊙	⊙	O	⊙
34. WASH SYSTEM, G.T.	⊙	O	⊙	O	O	O	⊙
35. L.O. SUPPLY PRESSURE	⊙	⊙	O	O	O	⊙	⊙
36. L.O. SUPPLY PRESSURE, LO	⊙	O	O	⊙	⊙	O	⊙
37. L.O. RESERVOIR LEVEL, LO	O	O	O	⊙	O	O	⊙
38. L.O. HEATER	O	O	O	O	O	⊙	O
39. L.O. SUPPLY TEMP, HI	⊙	⊙	O	⊙	⊙	O	O
40. L.O. FILTER D.P., HI	⊙	⊙	O	⊙	O	⊙	⊙
41. L.O. PUMP RUNNING, STBY.	⊙	⊙	O	⊙	O	O	⊙
42. L.O. PUMP RUNNING, EMG.	O	⊙	O	⊙	O	O	⊙
43. INLET AIR FILTER D.P., HI	⊙	⊙	O	⊙	⊙	O	⊙
44. GAS DETECTION LEVEL, HI	⊙	⊙	O	⊙	⊙	O	⊙
45. FIRE/GAS MONITOR FAILURE	⊙	O	O	⊙	O	O	⊙

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CONTROL, INSTRUMENT AND ALARM LIST (3.9.3.2) - CONTINUED

DESCRIPTION	OPT.	IND.	CONT.	AL.	SD.	LOC.	REM.
46. Enclosure Temperature, Hi	⊙	O	O	⊙	⊙	O	⊙
47. Fire System Disabled	⊙	O	O	⊙	O	O	⊙
48. Fire	⊙	O	O	⊙	⊙	O	⊙
49. Fire/Gas System Discharged	⊙	O	O	⊙	⊙	O	⊙
50. Control Voltage, Lo	⊙	O	O	⊙	O	O	⊙
51. Battery Voltage, Lo	O	O	O	⊙	⊙	O	⊙
52. Battery Charger Failure	O	O	O	⊙	O	O	⊙
53. Reset/Lamp Test	⊙	O	⊙	O	O	O	⊙
54. Horn Silence	⊙	O	⊙	O	O	O	⊙

ABBREVIATIONS

AL = ALARM
AUTO = AUTOMATIC
CON = CONTROL
D.P. = DIFFERENTIAL PRESSURE
EMG = EMERGENCY
GG = GAS GENERATOR
GT = GAS TURBINE
IND = INDICATOR
L.O. = LUBE OIL
LOC = LOCAL
MAN = MANUAL
OPT = OPTIONAL
PRESS = PRESSURE
PT = POWER TURBINE
REM = REMOTE
SD = SHUTDOWN
STBY = STANDBY
TEMP = TEMPERATURE

NOTES: ______

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INSPECTION AND TESTING (SEC. 4)

SHOP INSPECTION AND TESTS: (4.1)

	REQ'D	WITNESSED	OBSERVED
SHOP INSPECTION (4.1.4)	O	O	O
HYDROSTATIC (4.3.2)	●	O	O
GAS GENERATOR (4.3.3)	●	O	O
COMPLETE UNIT - NO LOAD (4.3.4)	●	O	O
AUXILIARY EQUIPMENT (4.3.5.1)	O	O	O
GAS TURBINE MECH. RUN (4.3.5.2)	O	O	O
GAS TURBINE PERFORM (4.3.5.3)	O	O	O
COMPLETE UNIT - PERF. (4.3.5.4)	O	O	O
ELECTRIC GENERATOR (4.3.5.5)	O	O	O
TORSIOGRAPH (4.3.5.6)	O	O	O
SOUND LEVEL (4.3.5.7)	O	O	O
POST TEST INSPECTION (4.3.5.7)	O	O	O
SPARE PARTS (4.3.5.0)	O	O	O
____	O	O	O
____	O	O	O
____	O	O	O
____	O	O	O

O MATERIALS INSPECTION REQUIREMENTS (4.2.2)

O SPECIAL CHARPY TESTING

O RADIOGRAPHY REQUIRED FOR ____

O MAGNETIC PARTICLE REQUIRED FOR ____

O LIQUID PENETRANT REQUIRED FOR ____

O UNITRASONIC REQUIRED FOR ____

O OTHER: ____

NOTES: ____

NOTES: ____

API SPEC 11 PGT-PACKAGED GAS TURBINE ELECTRIC A.C. GENERATOR DATA SHEETS

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GENERAL

APPLICABLE TO: O PROPOSAL O PURCHASER O AS BUILT

☐ MANUFACTURER ____ ☐ TYPE ____ ☐ MODEL ____ ☐ SERIAL NO. ____
☐ RATED OUTPUT, CONTINUOUS DUTY, KW ____ ☐ OVERLOAD CAPABILITY, KW ____
☐ RATED VOLTAGE, MV ____ ☐ RATED FREQUENCY, HZ ____
☐ RATED POWER FACTOR, % ____ ☐ PHASE/CONNECTION ____
☐ RATED TOTAL TEMPERATURE, °C ____ ☐ INSULATION CLASS ____

PERFORMANCE

☐ ARMATURE CURRENT AT RATED OUTPUT, AMP ____ ☐ SHORT CIRCUIT RATIO ____ ☐ $(I2)^2t$ ____
☐ FIELD VOLTAGE/CURRENT AT RATED OUTPUT, V/A ____ / ____ ☐ EXCITER FIELD CURRENT AT RATED OUTPUT, AMP ____
RECOVERY CHARACTERISTICS ARE APPLICATION OF RATED LOAD:
☐ MAXIMUM VOLTAGE DIP, % ____ ☐ MAXIMUM UNDERSPEED, % ____
☐ MAXIMUM TIME TO RETURN TO RATED VOLTAGE, SEC. ____

RECOVERY CHARACTERISTICS AFTER REJECTION OF RATED LOAD:
☐ MAXIMUM VOLTAGE OVERSHOOT, % ____ ☐ MAXIMUM OVERSPEED, % ____ ☐ MAXIMUM TIME TO RETURN TO RATED VOLTAGE, SEC ____
TOTAL EFFICIENCY AT RATED CONDITIONS:
☐ AT 110% RATED OUTPUT, % ____ ☐ AT 100% RATED OUTPUT, % ____ ☐ AT 90% RATED OUTPUT, % ____
☐ AT 75% RATED OUTPUT, % ____ ☐ AT 50% RATED OUTPUT, % ____ ☐ AT 25% RATED OUTPUT, % ____

REACTANCE CHARACTERISTICS AT RATED OUTPUT, PER UNIT:
☐ SYNCHRONOUS, DIRECT AXIS, Xd ____ ☐ SYNCHRONOUS, QUADRATURE AXIS, Xq ____
☐ TRANSIENT, DIRECT AXIS, X'dv/X'di ____ / ____ ☐ TRANSIENT, QUADRATURE AXIS, X'qv/X'qi ____ / ____
☐ SUBTRANSIENT, DIRECT AXIS, X"dv/X"di ____ / ____ ☐ SUBTRANSIENT, QUADRATURE AXIS, X"qu/X"qi ____ / ____
☐ NEGATIVE SEQUENCE, X2v/X2i ____ / ____ ☐ ZERO SEQUENCE, Xo ____
☐ LEAKAGE, Xl ____

RESISTANCE AT 20°C, OHMS PER PHASE: ☐ STATOR ____ ☐ ROTOR ____
☐ ZERO SEQUENCE RESISTANCE, PER UNIT, Ro ____ ☐ POSITIVE SEQUENCE RESISTANCE PER UNIT, R1 ____
☐ NEGATIVE SEQUENCE RESISTANCE, PER UNIT, Ro ____ ☐ CAPACITANCE TO GROUND, PER PHASE, mf ____

FIELD TIME CONSTANTS, SEC. AT 125°C:
☐ OPEN CIRCUIT TRANSIENT, DIRECT AXIS, T'do ____
☐ OPEN CIRCUIT TRANSIENT, QUADRATURE AXIS, T'qo ____
☐ OPEN CIRCUIT SUBTRANSIENT, DIRECT AXIS, T"do ____
☐ OPEN CIRCUIT SUBTRANSIENT, QUADRATURE AXIS, ____
☐ SHORT CIRCUIT TRANSIENT, LINE TO NEUTRAL, T'd1 ____
☐ SHORT CIRCUIT TRANSIENT, LINE TO LINE, T'd2 ____
☐ SHORT CIRCUIT TRANSIENT, THREE PHASE, T"d3 ____
☐ SHORT CIRCUIT SUBTRANSIENT, T"do ____

ARMATURE TIME CONSTANTS, SEC @ 100°C:
☐ SHORT CIRCUIT, LINE TO NEUTRAL, Ta1 ____ ☐ SHORT CIRCUIT, LINE TO LINE, Ta2 ____
☐ SHORT CIRCUIT, THREE PHASE, Ta3 ____

NOTES: ____

API SPEC 11 PGT-PACKAGED GAS TURBINE ELECTRIC A.C. GENERATOR DATA SHEETS

PAGE 2 OF 2
JOB NO.____ ITEM____
P.O. NO.____ DATE____
INQUIRY NO.____ BY____
REVISION____ DATE____

COOLING SYSTEM

TYPE OF COOLING SYSTEM:

O AIR O AIR/WATER O AIR/AIR O OTHER____

☐ TOTAL AIR FLOW, SCFM____
☐ MAX ALLOWABLE RESTRICTION, IN H_2O____
☐ COOLING AIR TEMPERATURE RISE, °F____
☐ HEAT REJECTION AT RATED OUTPUT, BTU/HR____
O OTHER____

WATER COOLER CHARACTERISTICS AT RATED OUTPUT:
☐ REQUIRED INLET TEMP, °F____
☐ REQUIRED FLOW, GPM____
O TYPE OF COOLING WATER____
☐ OUTLET TEMP, °F____
☐ REQUIRED PRESSURE, PSIG____

LUBRICATION SYSTEM

TYPE OF LUBRICATION SYSTEM:
O GREASE O PRESSURIZED O OTHER____
O PROVIDE API 614 DATA SHEETS
O LUBE OIL FLOW, GPM____
☐ LUBE OIL PRESSURE, PSIG____

☐ LUBE SPECIFICATION____
☐ HEAT REJECTION AT RATED OUTPUT, BTU/HR____
☐ OTHER____

PHYSICAL CHARACTERISTICS

☐ TYPE OF BEARINGS____
☐ TYPE OF ROTOR____
☐ WEIGHT OF STATOR____ ☐ WEIGHT OF ROTOR____ ☐ WEIGHT, TOTAL____
☐ ROTOR WR^2, $1b{=}ft^2$____
☐ TYPE OF EXCITER____ ☐ TYPE OF VOLTAGE REGULATOR____
O NUMBER/TYPE OF STATOR TEMPERATURE DETECTORS____
O NUMBER/TYPE OF VIBRATION PROBES____
O OTHER____

INSPECTION AND TESTING

	REQUIRED	OBSERVED	WITNESSED
APPENDIX E INSPECTION AND TEST	O	O	O
WINDING IMMERSION TEST (E.2.5)	O	O	O
NO LOAD VIBRATION (E.5.5)	O	O	O
HEAT RUN (E.5.6)	O	O	O
ANSI C50.10 (E.6.1)	O	O	O
ANSI C50.12 (E.6.1)	O	O	O
ANSI C50.14 (E.6.1)	O	O	O
IEEE 115 (E.6.1	O	O	O
NEMA MG1-22-51 (E.6.1)	O	O	O
OTHER:____	O	O	O

NOTES:____

APPENDIX B

TYPICAL PACKAGER DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______ DATE ______
REQUISITION NO. ______ DATE ______
INQUIRY NO. ______ DATE ______
PAGE 1 OF 3 BY ______
REVISION ______
UNIT ______
NO. REQUIRED ______

FOR ______
SITE ______
SERVICE ______

Proposal[a] — Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.

Final[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.
Packager shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

Final—Received from packager
Final—Due from packager[c]
Review—Returned to packager
Review—Received from packager
Review—Due from packager[c]

Proposal[a]	Review[b]	Final[b]	DESCRIPTION	Review—Due from packager[c]	Review—Received from packager	Review—Returned to packager	Final—Due from packager[c]	Final—Received from packager
			1. Dimensional Outline Drawing and List of Connections for Complete Package.					
			2. Enclosure Drawings and Details.					
			3. Air Inlet System.					
			4. Exhaust System.					
			5. Water Wash System, Schematics and Bill of Material.					
			6. Shaft Coupling(s) Assembly Drawing(s) and Bill(s) of Materials(s).					
			7. Bleed Air/cooling Air sealing and Leak-off Schematic(s) and Bill(s) of Material(s).					
			8. Fuel System(s) Schematic(s) and Bill(s) of Material(s).					
			9. Fuel System(s) Assembly Drawing(s) and List(s) of Connections.					
			10. Lube-oil and Control-oil Schematic(s) and Bill(s) of Material(s).					
			11. Lube-oil and Control-oil Assembly Drawing(s) and List(s) of Connections.					
			12. Seal System Schematic(s) and Bill(s) of Material(s).					
			13. Starting System Schematic(s) and Bill(s) of Material(s).					
			14. Anti-icing System Schematic(s) and Bill(s) of Material(s).					
			15. Fire Protection/Gas Detection Schematic(s) and Bill(s) of Material(s).					
			16. Control System Control Logic Diagram.					
			17. Electrical, Control and Instrumentation Schematic(s) and Bill(s) of Material(s).					
			18. Electrical, Control and Instrumentation Interconnecting Wiring Diagram.					
			19. Control Panel Plan and Elevation Drawings(s).					
			20. Steam/water Injection System Schematic(s) and Bill(s) of Material(s).					
			21. Steam/water Injection System Arrangement Drawing(s).					
			22. Steam/water Quality and Quantity Requirement.					
			23. Tabulation of Utility Requirements.					
			24. Instrument Set Point List.					
			25. Output Shaft Speed Versus Site Rated Power (certified).					
			26. Ambient Temperature Versus Site Rated Power.					
			27. Steam/water Injection Rate Versus Incremental Power Output.					

[a]Proposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

TYPICAL PACKAGER DRAWING AND DATA REQUIREMENTS

JOB NO. ____ ITEM NO. ____
PURCHASE ORDER NO. ____ DATE ____
REQUISITION NO. ____ DATE ____
INQUIRY NO. ____ DATE ____
PAGE 2 OF 3 BY ____
REVISION ____
UNIT ____
NO. REQUIRED ____

FOR ____
SITE ____
SERVICE ____

Proposal[a] — Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.

Final[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.
Packager shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

Final—Received from packager
Final—Due from packager[c]
Review—Returned to packager
Review—Received from packager
Review—Due from packager[c]

Proposal	Review	Final	DESCRIPTION	Review—Due from packager	Review—Received from packager	Review—Returned to packager	Final—Due from packager	Final—Received from packager
			28. Inlet Pressure Drop Versus Site Rated Power Loss.					
			29. Exhaust Pressure Drop Versus Site Rated Power Loss.					
			30. Power Turbine Output Shaft Speed Versus Torque Curve.					
			31. Heat Rate Correction Factors.					
			32. Anti-icing Derate (bleed air operation).					
			33. Generator Output Performance Curve.					
			34. Centrifugal Compressor Performance - Allowing Minimum 4% Site Power Reserve.					
			35. Centrifugal Pump Performance - Allowing Minimum 3% Site Power Reserve.					
			36. Lateral Critical Analysis Report.					
			37. Torsional Critical Analysis Report.					
			38. Stiffness Map.					
			39. Transient Torsional Analysis.					
			40. Allowable Flange Loading(s).					
			41. Alignment Diagram.					
			42. Weld Procedures.					
			43. Test Procedures.					
			44. Hydrostatic Test Logs.					
			45. Mechanical Run Test Logs.					
			46. Test Logs.					
			47. Performance Test Logs.					
			48. Non-destructive Test Procedures.					
			49. Special/Optional Test Procedures/Logs [4.3.5].					
			50. Mill Test Reports (certified).					
			51. Data Sheets [Appendix A].					
			52. As-build Dimensions and Data.					
			53. Installation Manual.					
			54. Operating and Maintenance Manuals.					

[a]Proposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

TYPICAL PACKAGER DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PAGE 3 OF 3 BY ______
DATE ______ REV. NO. ______

Proposal[a] — Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.

Final[b] — Packager shall furnish ____ copies and ____ transparencies of drawings and data indicated.
Packager shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

Proposal[a]	Review[b]	Final[b]	DESCRIPTION	Review—Due from packager[c]	Review—Received from packager	Review—Returned to packager	Final—Due from packager[c]	Final—Received from packager
			55. Spare Parts Recommendation.					
			56. Fabrication and Delivery Schedule.					
			57. Packing List.					
			58. List of Special Tools for Maintenance.					
			59. Foundation Plan/Anchor Bolt Layout.					
			60. Lift Drawings.					
			61. User's List.					
			62. Operational Restrictions.					

[a]Proposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:
1. Send all drawings and data to ______________________________.
2. 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.
3. See expanded description of specified items below.

Nomenclature:
______ S—number of weeks prior to shipment.
______ F—number of weeks after firm order.
______ D—number of weeks after receipt of approved drawings.

Packager ______________________________
Date __________ Packager Reference ______________________________
Signature ______________________________
(Signature acknowledges receipt of all instructions)

DESCRIPTION

The following paragraphs are identified directly with the applicable line item requirements for Packager Drawing and Data Requirements (PDDR). The following PDDR Schedules shown are self-descriptive in regard to information required; others are not. These expanded paragraphs will clarify and/or suggest the intent for information desired.

GENERAL

1. Dimensional outline drawing and list of connections for complete package.
2. Enclosure drawings showing details for access and maintenance including [2.2.3]:
   a. Lights.
   b. Ventilation System.
   c. Drains.
   d. Maintenance lifting equipment such as overhead beams and blocks.
   e. Doors/Locks.
   f. Windows.
3. Air inlet system including dimensional outline drawings, required structural supports and maintenance access [2.2.2].
   a. Access platforms, ladders, doors, windows, etc.
   b. Support structure, if elevated by specification or design.
   c. Utility connections, if not shown in item 1 above.
   d. Materials of construction, controls and instrumentation.
   e. Material description of each inlet air filter stage.
   f. Proposal shall reference the standards or test procedures used in determining filter efficiency. The packager shall state the water absorption capacity of each filter stage or element.
   g. The packager shall furnish in his proposal full details of inlet silencer construction.
4. Exhaust system dimensional outline drawings, required structural support and maintenance access including:
   a. Materials of construction.
   b. Details of silencer construction.
5. Water wash system, schematics, and bill(s) of material(s).
6. Shaft coupling assembly drawing(s) and bill(s) of material(s) including:
   a. Hydraulic mounting procedures.
   b. Shaft end gap and tolerance.
   c. Coupling guards.
   d. Thermal growth from 59°F (15°C) baseline.
7. Bleed air/cooling air sealing and leak-off schematic(s) and bill(s) of material(s).
8. Fuel system(s) schematic(s) and bill(s) of materials.
9. Fuel system(s) component assembly drawings and list of connections.
10. Lube-oil and control-oil schematic(s), including:
    a. Steady-state and transient oil flows and pressures at each use point.
    b. Control, alarm and trip settings (pressures and recommended temperatures).
    c. Heat loads at each use point at maximum load.
    d. Utility requirements, including electrical, water, and air.
11. Lube-oil and control assembly drawing(s) and list(s) of connections.
12. Seal system schematic(s), and bill(s) of material(s).
13. Starting system, schematic(s) and bill(s) of material(s).
14. Anti-Icing system, schematic(s) and bill(s) of material(s).
15. Fire protection/gas detection systems, schematic(s) and bill(s) of materials.
16. Control system control logic diagram.
17. Electrical, control and instrumentation schematic(s) and bill(s) of materials.
18. Electrical, control and instrumentation interconnection wiring diagram.
19. Control panel plan and elevation drawings.
20. Steam/water injection system schematic and bill of materials, including steady-state and transient flows and pressures at each use point.
21. Steam/water injection system arrangement, including size, rating, and location of all customer connections.
22. Steam/water quality and quantity requirements.
23. Tabulation of utility requirements (may be on "as built" purchaser data sheets).
24. Instrument set point list.

PACKAGE PERFORMANCE DATA/CURVES

25. Output shaft speed versus site rated power curves at site rated conditions with normal fuel (certified curves).
26. Ambient temperature versus site rated power curve at rated speed with normal fuel.
27. Incremental power versus water or steam system injection rate curves (required only if injection supplied).
28. Inlet pressure drop versus site rated power loss.
29. Exhaust pressure drop versus site rated power loss.
30. Power turbine output shaft speed versus torque curve (include starter, if applicable).
31. Heat rate correction factors for the curves listed in Items 25, 26, 27, 28 and 29 at conditions other than size rated as follows:
    a. Ambient pressure to maximum and minimum values listed on the data sheets in increments agreed at order (usually no significant change).

32. Anti-Icing (Bleed Air) derate curve.
    b. Ambient temperature to maximum and minimum values listed on the data sheets in increments agreed at order.
    c. Power output shaft speed from 80 to 105 percent in 5-percent increments (2-shaft only).
    d. Exhaust pressure to maximum and minimum values listed on the data sheets in increments agreed at order.
    e. Injection system rate changes (fuel only - treat injection liquid as "compressed air").

DRIVEN EQUIPMENT PERFORMANCE DATA/ CURVES

33. Generator output performance vs ambient, vs coolant temperatures, efficiency vs output.
34. Centrifugal compressor performance allowing minimum 4% site power reserve:
    a. Polytropic head and Polytropic efficiency versus ICFM curves for each section or casing on multiple-section or multiple-casing compressors, in addition to composite curves at 80, 90, 100 and 105 percent of rated speed.
    b. Curves showing discharge pressure and brake horsepower versus ICFM at rated conditions for each section or casing on multiple-section or multiple-casing compressors, in addition to composite curves at 80, 90, 100, and 105 percent of rated speed. For services with gases of varying molecular weights (MW), curves shall also be furnished at maximum and minimum MW. For compressors in air service, curves shall also be furnished at three additional specified inlet temperatures.
    c. Curve showing the pressure above suction pressure behind the balance drum versus compressor loading of the thrust shoes, both in pounds per square inch (BAR), using rated conditions as the curve basis. The curve shall extend from a pressure equal to section pressure behind the drum to a pressure corresponding to at least 500 psi (34.5 BAR) unit loading on the thrust shoes. Balance drum outside diameter, effective balance drum area, and expected and recommended maximum allowable pressure behind the balance drum shall be shown on the curve sheet.
35. Centrifugal pump performance curves - allowing minimum 3 percent site power reserve.

DESIGN DATA/REPORTS

36. Lateral critical analysis report, including but not limited to the following:
    a. Method used (complete description).
    b. Graphic display of critical speeds vs. 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:
        1. Pad angle.
        2. Pivot clearance.
        3. Pad clearance.
        4. Preload.
37. Torsional critical analysis report, including but not limited to the following:
    a. Complete description of method used.
    b. Graphic display of mass elastic system.
    c. Tabulation identifying the mass moment and torsional stiffness for 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.
38. Stiffness Map.
39. Transient torsional analysis for all units using synchronous starter motors (mandatory), driving synchronous generators, or other driven load.
40. Allowable flange loading(s) for all customer connections, including anticipated thermal movements referenced to a defined point.
41. Coupling alignment diagram, including recommended coupling limits during operation.

    Note: *All shaft-end position changes and support growths from 59°F (15°C) ambient reference or other temperature specified by the Purchaser.*
42. Weld procedures for fabrication and/or repair (see para. 2.6.2, 3.6.1.11, and 4.2.2.5.2).

TESTING

43. Test Procedures.
44. Hydrostatic test logs (certified) (4.3.2).
45. Mechanical run test logs, including but not limited to the following (4.3.3, 4.3.4, and 4.3.5.2):
    a. Oil flow, pressures, and temperatures.
    b. Vibration, including x-y plot of amplitude and phase angle versus revolutions per minute during startup and coastdown.
    c. Bearing metal temperatures.
    d. Observed critical speeds (for flexible rotors).
    e. Exhaust gas temperature.
46. Test Logs.
    a. Complete Unit No-load Mechanical Running Test [4.3.4].
    b. Full-Pressure/Full Load/Full Speed Test [4.3.5.4].
    c. Driven Equipment Test(s).
    d. Torsional Test [4.3.5.6].
    e. Sound Level Test [4.3.5.7].
    f. Post Test Inspection [4.3.5.8].

g. Spare Parts Test [4.3.5.9].

47. Performance test logs and report in accordance with ASME PTC-22, Section 6 (1985) as supplemented by ASME PTC-1 (1986) subpart K, para. 3.30 and 3.31 [4.3.5.3 and 4.3.5.4].

48. Non-destructive test procedures as itemized on P.O. data sheets or PDDR form.

49. Procedures for any special or optional test (see para 2.6.1.7, 4.2, and 4.3.4).

50. Mill test reports (certified) of items as agreed in the pre-commitment or pre-inspection meeting(s).

DATA/MANUALS

51. As-built data sheets.

52. 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 disc.
4. Each interstage labyrinth.
5. Each journal bearing.

b. Each wheel or disc bore (for "stacked" rotors) and O.D.

c. Each labyrinth or seal-ring bore.

d. Thrust-collar bore (for separate collars).

e. Each journal-bearing ID.

f. Thrust-bearing concentricity (axial runout).

g. Metallurgy and heat treatment for:

1. Shaft.
2. Impellers or bladed discs.
3. Thrust collar.
4. Blades, vanes, and nozzles.

53. Installation manual describing the following (see 5.2.5.2):

Section 1 — Installation.

a. Storage.

b. Foundation.

c. Grouting.

d. Setting equipment, rigging procedures, component weights, and listing diagram.

e. Alignment.

f. Piping recommendations, including allowable flange loads.

g. Composite outline drawings for driver/driven-equipment train, including anchor-bolt locations.

h. Dismantling clearances.

54. Operating and maintenance manuals describing the following (see 5.2.5.3):

Section 2 — Operation.

a. Startup.

b. Normal shutdown.

c. Emergency shutdown.

d. Operating limits.

e. Lube-oil recommendations.

f. Routine operational procedures.

Section 3 — Disassembly and Reassembly Instructions:

a. Rotor in casing.

b. Rotor unstacking and restacking procedures.

c. Journal bearings (for tilting-pad bearings, provide "go/no-go" dimensions with tolerances for three-step plug gauges).

d. Thrust bearing.

e. Seals (maximum and minimum clearances).

f. Thrust collar.

g. Wheel reblading procedures.

h. Boring procedures and torque values.

Section 4 — Performance Curves: (Data)

a. Shaft speed versus site rated power.

b. Ambient temperature versus site rated power.

c. Output power shaft speed/torque curve.

d. Incremental power output/system injection rate curve (optional).

e. Heat correction factors.

f. First-stage pressure versus thrust.

Section 5 — Vibration Analysis Data; per item 28, 29, 30, 33 above.

Section 6 — As-Built Data.

a. As-built data sheets.

b. As-built dimensions or data (see 47 above).

c. Hydrostatic test logs (see 44 above).

d. Mechanical run test logs (see 45 above).

Section 7 — Drawing and Data.

a. Certified dimensional outline drawing and list of connections.

b. Cross-sectional drawing and bill of materials.

c. Rotor drawing(s) and bill of materials.

d. Thrust-bearing assembly drawing and bill of materials.

e. Journal-bearing assembly drawing and bill of materials.

f. Seal-component drawing and bill of materials.

g. Lube-oil schematic and bill of materials.

h. Lube-oil arrangement drawing and bill of materials.

i. Lube-oil component drawings and data.

j. Electrical and instrumentation schematics and bill of materials.

k. Electrical and instrumentation arrangement drawing and list of connections.

l. Control- and trip-system drawings and data.

m. Trip- and throttle-valve construction drawing.

55. Spare parts lists with stocking level recommendation for commissioning/startup, and operational requirements.

56. Fabrication and delivery schedule, including vendor buyouts and milestones.

57. Shipping list, including all major components that will ship separately.

58. List of special tools furnished for maintenance. Identify any metric items included in the offering.

59. Foundation plan, including data per 51. Section 1.e above, and information per para 3.2.

60. Instrument set-point list.

61. Lift drawings: Sketches indicating methods of lifting the assembled machine(s) and major components. If "typical" drawings, schematics, and bill of materials are used, they shall be marked up to show correct weight and dimension data, and to reflect the actual equipment and scope proposed.

62. User list: A list of similar machines installed and operating under analogous conditions to that proposed.

63. Operational restrictions.

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, it shall be expressed 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 2.3.6.6 of this procedure.

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 6000 pounds would be assumed to impose a static weight load of 3000 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 residual unbalance, a known trial weight is attached to the rotor sequentially in six 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 2 ounce-inches, the trial weight should cause 2-4 ounce-inches 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 place. 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 also generally indicates that the rotor was not balanced precisely enough.). If the trial weight was added to the heavy spot the first meter reading should be at least twice as much as the last reading taken before the trial weight was added. All checks must be run using one sensitivity range on the balancing machine.

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.

C.4.2.5 Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance. 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 approximately sinusoidal curve. An average of the maximum and minimum meter readings represents the effect of the trial weight. One-half the sinusoidal variation represents the effect of the residual unbalance.

C.4.2.6 Repeat the steps described in C.4.2.1 through C.4.2.5 for each balance plane. This procedure shall not be considered complete until the readings have been plotted and the residual unbalance has been calculated for each balancing 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.5 Example. Using twelve trial weight positions, run a residual unbalance check on a centrifugal pump that operates at 3600 revolutions per minute. The two-bearing rotor is symmetrical and weighs 1800 pounds.

The journal static weight load W is approximately one-half the total weight of the rotor, or 900 pounds. Therefore, the maximum allowable residual unbalance in each plane is calculated as follows:

$$U_{max} = \frac{4W}{N} = \frac{(4)(900)}{3600} = 1 \text{ ounce-inch}$$

The trial weight should be between 1 and 2 ounce-inches. In this case, 1 ounce-inch is selected. The results of the trial weight runs are plotted in Figure C-1.

The trial weight's effect (z) on the meter readings can be calculated as the average of the maximum and minimum readings. The maximum reading shown in Figure C-1 is 9 and the minimum reading is 7; therefore, z = 8.

The average meter reading is equivalent to the trial unbalance. A trial unbalance of 1 ounce-inch was selected, so a meter reading of 8 represents 1 ounce-inch.

The residual unbalance's effect (y) on the meter reading is represented on the graph by one-half the sinusoidal variation, or one-half the difference between the maximum and minimum readings. Therefore, y = (9-7)/2 = 1.

The one unit of residual unbalance indicated in the meter readings can now be converted to residual unbalance in ounce-inches as follows:

$$U = \frac{y \text{ X Trial unbalance weight}}{z}$$

Where:

U = residual unbalance, in ounce-inches.

y = effect of residual unbalance on the meter reading (one-half the difference between the maximum and minimum meter readings).

z = effect of the trial unbalance weight on the meter reading (one-half the sum of the maximum and minimum meter readings).

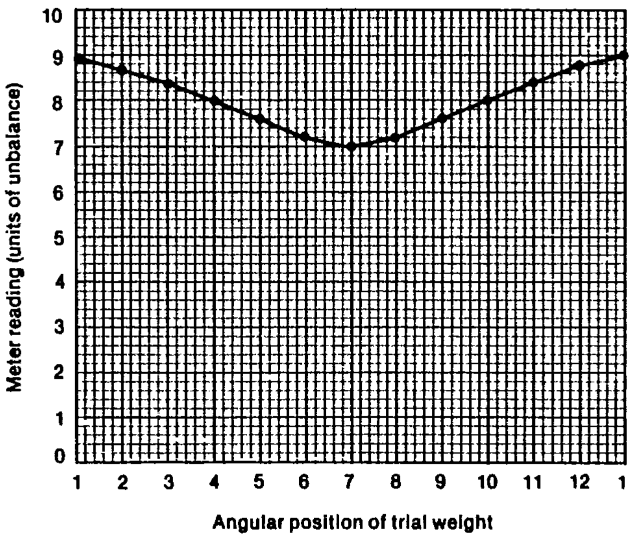
In the example,

$$U = \frac{1 \text{ X } 1 \text{ ounce-inch}}{8} = 0.125 \text{ ounce-inch}$$

This is less than the maximum allowable residual unbalance of 1 ounce-inch calculated at the beginning of the procedure.

Equipment Item No. ________

RESIDUAL UNBALANCE WORK SHEET



Rotor speed (*N*) _3600_ rpm

Journal static weight of rotor (*W*) _900_ lb.(kg)

Balance tolerance _1.0_ oz.-in. (g-mm) (See note.)

Trial weight (1) _1.0_ oz.-in. (g-mm)

$\frac{\text{Max. reading} - \text{Min. reading}}{2}$ = (2) _1.0_

$\frac{\text{Max. reading} + \text{Min. reading}}{2}$ = (1) _8.0_

Residual unbalance =

$\frac{(1)\ 1.0 \times (2)\ 1.0}{(1)\ 8.0}$ = _0.125_ oz.-in. (g-mm)

Note: If not specified, balance tolerance is 4*W*/*N* oz.-in. (6350*W*/*N* g-mm).

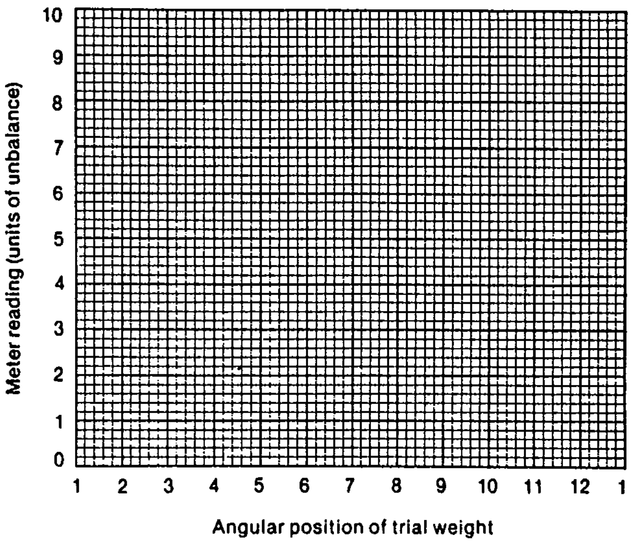
Witnessed ________________

Right Plane

FIGURE C-1
SAMPLE PLOT AND CALCULATION OF RESIDUAL UNBALANCE

Equipment Item No. ________

RESIDUAL UNBALANCE WORK SHEET



Rotor speed (N)______rpm

Journal static weight of rotor (W)______lb. (kg)

Balance tolerance______oz.-in. (g-mm) (See note.)

Trial weight ① ______oz.-in. (g-mm)

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

$\frac{\text{Max. reading} + \text{Min. reading}}{2}$ = ③ ______

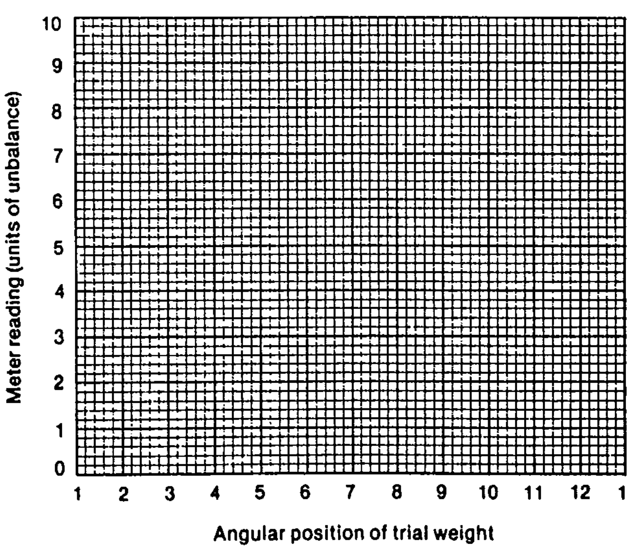
Residual unbalance =

$\frac{① \_\_\_\_ \times ② \_\_\_\_}{③ \_\_\_\_}$ = ______oz.-in. (g-mm)

Note: If not specified, balance tolerance is $4W/N$ oz.-in. ($6350W/N$ g-mm).

Witnessed ____________________

Right Plane



Rotor speed (N)______rpm

Journal static weight of rotor (W)______lb. (kg)

Balance tolerance______oz.-in. (g-mm) (See note.)

Trial weight ① ______oz.-in. (g-mm)

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

$\frac{\text{Max. reading} + \text{Min. reading}}{2}$ = ③ ______

Residual unbalance =

$\frac{① \_\_\_\_ \times ② \_\_\_\_}{③ \_\_\_\_}$ = ______oz.-in. (g-mm)

Note: If not specified, balance tolerance is $4W/N$ oz.-in. ($6350W/N$ g-mm).

Witnessed ____________________

Left Plane

RESIDUAL UNBALANCE WORK SHEET

APPENDIX D
PURCHASER'S CHECKLIST

This checklist is to be used to indicate the purchaser's specific requirements when this recommended practice indicates that a decision is required by the purchaser. In this procedure, these items are indicated by a bullet preceding the paragraph number.

The checklist should be used in conjunction with the data sheets (Appendix A). Below, the purchaser should indicate yes or no by a mark in the appropriate space with an X, or fill in the requirements.

Note: *The use of this checklist is optional where these items are covered by a narrative specification, provided by the purchaser.*

Paragraph	Requirement Yes	No	Basic Design	Data Sheet Reference
			PERFORMANCE REQUIREMENTS	API 11PGT
2.1.3 2.1.4 2.1.5	___ ___ ___	___ ___ ___	Purchaser is required to complete all performance requirements on the applicable data sheets including notes for special starting and transient requirements.	API 617 API 610 API 613
2.1.6	X	___	INSTRUMENTATION Purchaser is required to complete the data sheets for the applicable equipment or specifically provide as a part of the job specification a detailed description of the instrumentation requirements.	API 11PGT API 616-3 API 616-4 API 616-10 API 616-6 API 616-7 API 614 API 617 API 610
2.1.9.1	X	___	SITE CONDITIONS Purchaser is required to complete the data sheets.	API 11PGT API 616-1 API 617 API 610
2.1.9.2	X	___	AREA CLASSIFICATION Define per NFPA 70, Articles 500, 501, and 502.	API 11PGT API 616-2
2.1.9.3	X	___	INDOORS/OUTDOORS Suggest further detail in Job specification.	API 11PGT API 616-1
2.1.9.4	X	___	ATTENDED/UNATTENDED Suggest further detail in Job specification.	API 11PGT API 616-1
2.1.10	___ ___	___ ___	NOISE - COMPLETE DATA SHEET	API 11PGT API 616-1 Line 36
2.1.11	X	___	EMISSIONS Purchaser is required to fill in Page 9, API Std 616	API 11PGT API 616-9 Line 22
2.1.12		___	FUELS Purchaser is required to fill in Page 2, API Std 616	API 11PGT API 616-2
2.2.3	___	___	OTHER EQUIPMENT The purchaser is expected to provide a specific specification that will list any other equipment required for the project such as:	

a. Combustion emission control system.
b. Driven equipment in accordance with applicable specifications.
c. Enclosure(s) for acoustical and/or fire protection.
d. Exhaust system (including expansion joints, silencers, structures).
e. Fuel conditioning.
f. Inlet evaporative air cooler.
g. Inlet anti-icing system.
h. Motor control center.
i. Process heat exchangers.
j. Recuperator or regenerator for turbine performance enhancement.
k. Starting system auxiliaries.
l. Steam or water injection fluid conditioning system.
m. Turbine load train condition monitoring equipment.
n. Uninterrupted Power Supply for controls, instrumentation, and operation.
o. Waste heat recovery systems.

Paragraph	Requirement Yes	No	Basic Design	Data Sheet Reference
2.2.5	___	___	MOTORS AND ELECTRICAL COMPONENTS The purchaser is required to fill in electrical requirements on data sheet area requirement and utilities available.	API 616-5 API 11PGT
2.2.6	___	___	OPERATING SPEED RANGE Speed Range, if known, is to be filled in. If not known, the process requirement limits should be explained in the Job Specification.	API 616-1 616-3
2.2.14	___	___	STEAM AND/OR WATER INJECTION The purchaser is to fill in injection requirements and include in the job specification any special requirements for power or emissions.	API 616-1
2.2.16.1	___	___	SPECIAL TOOLS AND FIXTURES Purchaser is to specify when vendor is to quote special tools as a part of the initial supply of the package.	API 11PGT
2.2.17	___	___	COMPARTMENT ENCLOSURE It is important for the purchaser to inform the packager of the enclosure requirements including noise (Par 2.1.10), and site conditions (Par 2.1.9).	API 616-1
2.3.1.2	___	___	GAS TURBINE DESIGN The job specification should explain to the purchaser the order of importance of governing specifications (Par 1.3).	API 11PGT
2.3.2.2	___	___	COUPLINGS Specify coupling requirements.	API 616 API 671
2.3.2.3	___	___	IDLING ADAPTER Specify if idling adapter is required for running mechanical test.	API 616 API 671
2.3.4.1	___	___	LOAD GEAR DESIGN Purchaser is to specify what specifications apply to the main load gear.	API 616 API 613 API 11PGT
2.3.4.3	___	___	GENERATOR MINIMUM LOAD For applications where long term operation at low power levels are expected, this requirement should be shown on data sheet and explained in job specification.	API 11PGT
2.3.5.2.2	___	___	COMBINED LUBE AND SEAL OIL SYSTEMS Separate or combined lube oil/seal systems are to be stated. Note: where seal systems are required (or preferred) that do not require oil, the purchaser should detail requirements in the job specification.	API 617 API 614
2.3.5.2.3	___	___	COMPRESSOR PERFORMANCE Performance/operating conditions are to be detailed on the compressor data sheets.	API 617
2.3.5.3.2	___	___	PUMP PERFORMANCE Performance/operating conditions are to be detailed on the pump data sheets.	API 610
2.3.5.4.2	___	___	RATING REQUIREMENTS Show ratings on data sheets.	ANSI 50.13 ANSI 50.14 API 11PGT
2.3.5.4.4	___	___	GENERATOR POWER SYSTEM Purchaser will provide a Generator Power System one line diagram.	API 11PGT
2.3.5.4.5	___	___	GENERATOR TESTING PER APPENDIX E	API 11PGT
2.4.2.2	___	___	EXCITING FORCES The purchaser should advise the packager of any external natural frequencies or exciting frequencies that may be excited by or may excite the natural frequency of the rotating equipment. These external forces and frequencies should be explained in the job specification.	

Paragraph	Requirement Yes	No	Basic Design	Data Sheet Reference
2.5.2.2.a	___	___	SUPPORT SYSTEM The purchaser shall identify the support system and any natural frequencies that might be present in the job specification.	API 11PGT
2.5.2.4.e	___	___	STIFFNESS MAP The purchaser shall specify when he requires a stiffness map.	API 11PGT (Doc.)
2.6.1	___	___	MATERIALS Purchaser is to show conditions that require special materials or coatings on the data sheets.	API 616 API 11PGT
2.6.1.4	___	___	CORROSIVE AGENTS Purchaser to specify corrosive agents in atmosphere, fuel, gas or fluid pumped, etc.	API 616-2 API 617 API 610
2.7.3	___	___	NAME PLATE DATA Complete name plate data per Paragraph 2.7.3.	
3.1.1	___	___	STARTER SYSTEM Purchaser to select starter system desired.	API 616
3.1.3	___	___	STARTER SIZING For single shaft engines, it is important for the packager to know any external loads that may be present during starting.	API 11PGT
3.2.1	___	___	GENERAL, FOUNDATION TYPE Purchaser to specify foundation type.	API 616
3.2.2.2	___	___	GROUT Purchaser to specify if special provisions must be made to the baseplate for use with epoxy grout.	API 11PGT
3.2.3.2	___	___	LEVELING PADS Purchaser to specify if leveling pads are required.	API 617
3.2.3.3	___	___	COLUMN MOUNTING Purchaser to specify column mounting if required.	JOB SPEC
3.2.3.5	___	___	LIFTING FRAME/SPREADER BARS Purchaser to specify if lifting frame or spreader bars are required.	JOB SPEC
3.2.3.6	___	___	NONSKID DECKING OR GRATING	JOB SPEC
3.3.1.1	___	___	ENCLOSURE SYSTEMS Purchaser to specify.	API 616
3.3.1.2	___	___	SOUND CONTROL Purchaser to specify. See Par 2.1.10.	API 11PGT
3.3.3.2	___	___	FIRE SUPPRESSION SYSTEM Purchaser to specify if required.	API 616 API 11PGT
3.3.3.4	___	___	FIRE DETECTION SYSTEMS Purchaser to specify if required	API 616 API 11PGT
3.3.4.1	___	___	ENCLOSURE VENT, POSITIVE OR NEGATIVE Purchaser to specify if positive or negative pressure enclosure is required.	API 11PGT
3.3.4.4	___	___	EXHAUST DUCTING, VENT Purchaser to specify vent system ducting requirements.	API 11PGT
3.4.1.2	___	___	AIR INLET SYSTEM Purchaser to specify optional inlet system features.	API 616
3.4.1.7	___	___	AIR INLET PATH MATERIALS Purchaser to specify if 304 SS air path materials are required.	API 616
3.4.1.8	___	___	AIR INLET PATH MATERIALS Purchaser to specify if galvanized materials are required for the air inlet path.	API 616
3.4.1.9	___	___	AIR FILTER HOUSE LOCATION Purchaser to specify if the air inlet house is to be elevated and who is to provide support.	API 11PGT

Paragraph	Requirement Yes	No	Basic Design	Data Sheet Reference
3.4.2.1			TYPE OF AIR INLET FILTER Purchaser to specify.	API 616
3.4.3.1	___	___	SILENCER Purchaser to specify. See Par. 2.1.10.	API 616-1
3.4.5.1	___	___	EVAPORATIVE COOLING Purchaser to specify.	API 616-9
3.4.5.7	___	___	ACCESS REQUIREMENTS Purchaser to specify if walkways, hand rails, and ladders are required to provide access to coolers.	API 11PGT
3.4.6.2	___	___	WATER WASH SYSTEM Purchaser to specify if water wash system is required.	API 11PGT
3.4.7.1	___	___	ANTI-ICING SYSTEM Purchaser to specify if anti-icing system is required.	API 616-9
3.5.1	___	___	CYCLE APPLICATION Purchaser to indicate turbine cycle (simple or recuperated)	API 616-1
3.5.2	___	___	EXHAUST SYSTEM SPECIAL REQUIREMENTS Purchaser to specify.	API 616-9
3.6.5.1	___	___	PROCESS PIPING Purchaser is to specify the extent of process piping required.	JOB SPEC
3.6.5.2	___	___	PIPING REVIEW Purchaser to specify amount of piping/ducting and auxiliary hardware that is to be reviewed by the packager.	JOB SPEC
3.7.6	___	___	OIL CHARACTERISTICS Purchaser to show lube oil preferred in job spec.	JOB SPEC API 616-10
3.8.1.2	___	___	FUEL COMPOSITION Purchaser to show fuel analysis.	API 616-2
3.8.2.2	___	___	RANGE OF HEATING VALVES Purchaser to show fuel analysis.	API 616-2
3.8.2.3.2	___	___	FUEL GAS COMPRESSION Purchaser to state fuel gas pressure available and if compression is required, who provides the compression system.	API 616-2 JOB SPEC
3.8.4.1	___	___	DUAL FUEL Purchaser to specify.	API 616-2
3.8.5.1	___	___	NOX SUPPRESSION Purchaser to specify requirements.	API 616-1 API 616-9
3.8.5.2	___	___	WATER/STEAM INJECTION The purchaser will specify the level of NOX suppression desired.	API 11PGT
3.9.1.1	___	___	ELECTRICAL AREA CLASSIFICATION Purchaser to specify the electrical area classification for controls and instrumentation.	API 11PGT
3.9.1.2.1	___	___	CONTROL SIGNAL Purchaser to specify.	API 616-3
3.9.1.3	___	___	A. C. POWER INTERRUPTION TIME PERIOD Purchaser to specify length of time of operation during loss of A.C. power.	API 616
3.9.1.4	___	___	CONTROL SYSTEM REDUNDANCY Purchaser to specify if redundant control is required.	API 616
3.9.2.3	___	___	STARTING WITHOUT A.C. UTILITY Purchaser to specify if black start capability is required.	API 11PGT
3.9.3.1	___	___	INSTRUMENT AND CONTROL PANEL Purchaser to specify in job specifications the control panel(s) and instrument requirements.	API 11PGT
3.10.1	___	___	ELECTRICAL (UTILITY) Purchaser to specify electrical utilities available.	API 616-5

Paragraph	Requirement Yes	No	Basic Design	Data Sheet Reference
3.10.2	___	___	DC POWER Purchaser to specify requirements.	API 616-5
3.10.6	___	___	TROPICAL LOCATION Purchaser to specify when tropical treatment is required.	API 616-5
4.1.4	___	___	INSPECTION/TESTING Purchaser to specify extent of participation in testing and inspections.	API 616-10
4.2.1.1.a	___	___	MATERIAL CERTIFICATION Purchaser to specify.	API 11PGT APPDX. B.
4.2.1.1.e	___	___	CLEARANCES Purchaser to specify if required.	API 11PGT APPDX. B.
4.2.1.3	___	___	SURFACE/SUBSURFACE EXAMINATION Purchaser to specify.	API 616-10
4.2.2.1	___	___	INSPECTION CRITERIA Purchaser to specify.	API 616-10
4.2.3.3	___	___	CLEANLINESS INSPECTION Purchaser to specify.	API 616-10
4.2.3.4	___	___	HARDNESS VERIFICATION Purchaser to specify.	API 616-10
4.3.2.2	___	___	GAS TURBINE CASING HYDROTESTING	API-11PGT
4.3.4.3.4	___	___	TAPE RECORDINGS - REAL TIME Purchaser to specify.	API 616-10
4.3.5	___	___	OPTIONAL TEST Purchaser to specify.	API 11PGT
			4.3.5.1 Auxiliary Equipment Test	
			4.3.5.2 Gas Generator/Power Turbine Mechanical Running Test	
			4.3.5.3 Gas Generator/Power Turbine Performance Running Test	
			4.3.5.4 Full-Pressure/Full-Load/Full Speed Test	
			4.3.5.5 Electrical Generator Test	ANSI 50.14
			4.3.5.6 Torsional Test	
			4.3.5.7 Sound-Level Test	ANSI 55.1
			4.3.5.8 Post Test Inspection	
			4.3.5.9 Spare Parts Test	
4.3.5.5.1	___	___	ELECTRICAL GENERATOR TESTING The purchaser is to specify that the generator shall be tested in accordance with Appendix E.	API 11PGT
4.3.5.5.2	___	___	LOAD PERFORMANCE TESTED The purchaser is to specify when the generator is to be load performance tested with turbine driver.	API 11PGT
4.4.1	___	___	LONG TIME STORAGE Purchaser to specify storage.	API 616-1
4.4.3.10	___	___	SPARE ROTOR STORAGE Purchaser to specify storage.	API 616-1
5.1.4	___	___	CURVES	
5.2.6	___	___	TECHNICAL DATA MANUAL Purchaser to specify if tape recordings of real time vibration data and optional test reports are and when required [Appendix B].	API 11PGT
E.5.6	___	___	TEST RUN AT RATED TEMPERATURE	API 11PGT
E.6.1	___	___	TESTING GENERATORS Purchaser to specify which specification the generator will be tested in accordance with.	API 11PGT
E.6.3.1	___	___	GENERATOR TO BE WARMED UP Purchaser to specify if generator is to be warmed up to rated stator and rotor temperatures.	API 11PGT

APPENDIX E
INSPECTION AND TESTING OF ELECTRIC AC GENERATORS

E.1 Scope and Conditions.

E.1.1 This Appendix covers minimum requirements for inspection and shop testing of AC generators in production services.

E.1.2 The inspection and testing requirements stated herein are those that shall be performed at the generator manufacturing facility prior to final assembly of the completed generator unit. The basic electrical design of the generator shall be in accordance with the applicable requirements of NEMA MG1-22 and the ANSI C50.10, C50.12, C50.13, and C50.14 Standards. Mechanical design qualities shall be equivalent to those required in the API RP 546.

E.1.3 Acceptance by purchaser of shop tests shall not constitute a waiver of requirements to meet field tests, if any, as specified in Purchaser's Quotation Request or Data Sheets.

E.1.4 The generator manufacturer/supplier shall be identified as the VENDOR throughout this Appendix.

E.2 Inspection.

E.2.1 Purchaser shall have access to all VENDOR quality control (QC) data and records pertaining to the purchase order, and may inspect or observe any manufacturing operation at any time during the manufacture. [4.1]

E.2.2 VENDOR shall record the following data or dimensions during manufacture, and make the records available for review by purchaser's inspector:

E.2.2.1 Diameter of shaft journals at center and both ends of the bearing (three readings per journal).

E.2.2.2 Bore diameter of bearings, vertical and horizontal, at both ends of the bearing (at least four readings per bearing).

E.2.2.3 Runouts of coupling face, outside diameter, and hub when specified to be mounted by VENDOR.

E.2.2.4 Runout (magnitude and position of the high point) of the rotor journals, and at a location on the shaft adjacent to the rotor core, before and after the core or poles are mounted on the shaft.

E.2.2.5 Air gap at a minimum of three locations (90 degrees apart) on both ends. Repeat with rotor rotated a half-revolution.

E.2.2.6 Residual unbalance values and location of balance weights placement on each shaft component during the rotor balance (weight, radial distance, and angular position oriented with respect to angular reference, such as a keyway).

E.2.2.7 All test and nondestructive examination results.

E.2.2.8 All nonconformances (corrected or uncorrected). This includes repair of:

(1) rotor, stator or exciter insulation

(2) interturn insulation

(3) rotor or stator cores

(4) castings or forgings

(5) bearing babbitt or insulation

Uncorrected nonconformances must be documented and approved by VENDOR Engineering and Quality Control.

E.2.3 Purchaser shall have the opportunity to examine parts (for dimensions and runout) on an observed basis to ensure compliance with the drawings in the following areas (where applicable) as a minimum [4.2.1.3a]:

E.2.3.1 Rotor bearing journals, shaft-fan and shaft-coupling fits, and mounting fits for rotor laminations and/or pole pieces.

E.2.3.2 Exciter-to-rotor mounting flange, centering rabbet, and bolt circle spacing.

E.2.3.3 Pole piece-to-rotor attachment and locking means, where applicable.

E.2.3.4 Bearing clearance, fit of bearing outside diameter to bearing housing, and bearing bracket fit. On radial or axial registered fits check roundness, concentricity, and runout. On insulated bearings check roundness, contact area, and electrical resistance of the insulation.

E.2.3.5 On totally enclosed machines, check that all frame fits are sealed or gasketed and have no gaps which would allow entrance of dust or water.

E.2.3.6 Stator bore length and diameter, rotor core length and maximum pole diameter, and air gap.

E.2.3.7 Retaining ring fit-up tolerance.

E.2.4 The purchaser shall have the opportunity to observe the complete stator core iron and winding before the insulation sealing/coating process is begun.

• **E.2.5** When specified, form-wound stators shall be given a winding immersion test in accordance with NEMA MG 1-20.48. Dielectric absorption and insulation resistance tests shall be made at 1000 VDC. The minimum acceptable insulation resistance shall be 50 megohms.

E.2.6 During manufacturing, VENDOR shall perform the following electrical tests and record all pertinent data.

E.2.6.1 Surge comparison tests in accordance with IEEE 522 shall be made on coils to check turn-to-turn insulation after assembly into stator core, wedging, and bracing of end turns, but before making up coil-to-coil connections. Peak test voltage shall be at least rated stator voltage: 1.414 X V_{LL}, where V_{LL} is the rated line-to-line voltage. VENDOR standard test voltage is acceptable if it exceeds the value given.

E.2.6.2 Prior to assembly of synchronous generators, resistance to field pole windings shall be tested to prove equal resistance. Maximum variation in pole resistance shall not exceed 2 percent.

E.2.6.3 After field poles are connected, 120 volt, AC power shall be applied to the field winding to check for shorted turns. Voltages across poles shall not vary by more than 10 percent. On units which will not be run-tested in the factory, a polarity test shall be made on the field poles.

E.2.7 VENDOR shall make available the records of all items listed in E.2.2 and E.2.3, balance data, residual unbalance records, all tests, and verification of compliance with E.3. These will be reviewed by the PURCHASER prior to release for shipment [4.2.1.1].

E.3 Balance Requirements.

E.3.1 Rotors shall be dynamically balanced. The use of solder or similar deposits is not acceptable. Parent metal removed to achieve balance shall be drilled out in a way that does not affect the structural strength of the rotor; chiseling or sawing is not permitted. Rotor balance shall be done with rotor supported on its shaft journals. Rotors in generators rated 1500 rpm synchronous speed and higher shall be balanced after protective coating of all parts.

E.3.2 Rotors with keyed couplings shall be balanced with half key(s) in place. A half key used for balancing shall be dynamically equivalent to a half key which completely fills the keyway.

E.3.2.1 The balancing machine shall have a resolution of half, or less of the maximum allowable residual unbalance defined in E.3.2.4. All rotor balancing shall be done on the same balancing machine at 800 to 1000 rpm unless specifically approved otherwise by the Purchaser.

E.3.2.2 All components to be added, such as fans or an exciter, shall be pre-balanced separately (to limits consistent with the equation given in E.3.2.4, for that component) before mounting on the rotor.

E.3.2.3 Balance corrections shall be made with fans removed unless otherwise specifically approved by Purchaser. Fans shall then be installed and corrections made to fans only. The actual balance correction weight, radius, and angular location, and the balance machine reading, shall be recorded during each balance iteration.

E.3.2.4 After balancing, the maximum allowable residual unbalance per correction plane shall be determined as follows:

$$U_{max} = 4W/N \qquad \text{(Equation E.1)}$$

In SI units, this converts to:

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

Where

Un_{max} = residual unbalance, in oz.-in (gram-millimeters) per plane

N = equipment synchronous speed, in revolutions per minute

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

E.3.3 The rotor's actual residual unbalance in each plane shall be documented. At least six points shall be plotted. Plots from this procedure shall accompany the test report and shall be furnished to purchaser prior to release for shipment [Appendix C].

E.3.4 Trim-balancing is not acceptable during the machine running tests. Balance weights shall not be changed or added after the dynamic balance effort has been completed. Any subsequent rebalancing requires a repeat of the rotor shaft balance effort.

E.3.5 Coupling hub(s) specified to be mounted by the VENDOR shall be rechecked for balance on the rotor at completion of the final rotor-fan balance [2.3.2.6]. If the rotor unbalance exceeds the allowable unbalance (4W/N per plane) after the coupling hub is mounted, the VENDOR and Purchaser shall mutually agree on the cause of the excess unbalance and the corrective action to be taken. In no case shall unbalance, due to the addition of the coupling, be corrected in the main body of the rotor, fan assemblies, etc. If coupling solo (idler) plates (allowing the machine to run uncoupled) are required, they shall be mounted with the coupling after final rotor-fan balance.

E.4 Test Preparation and Setup.

E.4.1 All tests shall be made with the shaft axis in the normal running position. The generator unit shall be mounted on a massive foundation having a natural frequency at least 25 percent removed from the generator rotational-speed/frequency. A massive foundation is one whose vibration is limited to 0.02 inch per second (peak, unfiltered) on test (in the vertical, horizontal, and axial planes) above any background vibrations. The generator feet shall be firmly clamped and properly shimmed. When a hold-down bolt is loosened, foot movement shall not exceed 0.001 inch.

E.4.2 When pressure or flood lubricated bearings are used, an adequately filtered lube oil system with 10-micron (nominal) filters or better shall be provided to supply clean oil at rated flow, pressure and temperature. The test-stand oil shall have a viscosity equivalent to that specified for field operation. If orifices are specified for the final installation, they shall be in place. Oil flow rate to each bearing shall be verified.

E.4.3 Automatic low lube-oil pressure shutdowns shall be used when testing pressure lubricated units. Backup pumps shall be used when testing non-ring lubricated bearings.

E.4.4 For each radial bearing: clearances, bearing-to-bearing-housing fit, and alignment shall be checked and recorded using assembled measurements. Bearing-to-journal contact pattern shall be checked. Axial line contact between shaft journal and the bearing bore shall be 80 percent minimum.

E.4.5 Noncontact, displacement probe calibration curves and slow-roll electrical and mechanical runout measurements shall be completed [E.5.1].

E.5 Vibration Requirements.

● **E.5.1** Where noncontact displacement type probes or provisions for probes are specified, electrical and mechanical runout of each probe area shall comply with the requirements of API Standard 670. Slow-roll runout magnitude and phase angle of the probe-track surface shall be recorded for each probe with the rotor at its magnetic center and rotating at 200-300 rpm. (This may be accomplished by either driving the generator unit with an adjustable speed drive or by letting the generator "coast" through this speed range.) Each probe, extension cable, and oscillator demodulator shall be calibrated (with curves plotted) prior to shop tests by the VENDOR. Calibration data shall be available for Purchaser's review.

E.5.2 During both no-load and load heat run tests, vibration measurements shall be made in each of the following locations using transducers indicated below:

Location	Measurement Transducer
Bearing Housing (both ends)	Seismic transducer or accelerometer (readings in vertical, horizontal or, preferably, in same direction as noncontact probes if supplied — and axial directions).
Shaft (both ends)	Noncontacting displacement type (readings in vertical and horizontal directions, and 90 degrees apart).

E.5.3 The radial vibration level measured on a bearing housing, in any plane, with generator operating at rated voltage and frequency and at any load, shall not exceed the following limits:

Synchronous Speed (rpm)	Unfiltered Amplitude* Peak-to-Peak (mils)	Maximum Discrete-Frequency** Velocity Zero-to-Peak (ips)
≤ 1200	2.0	0.1
1201 to 1800	1.6	0.1
1801 to 3600	0.8	0.1

*The maximum unfiltered axial direction displacement level shall not exceed 1.5 times the radial unfiltered displacement limits shown above.

**1X and 2X running speed frequency, 1X and 2X line frequency. The instrument filter bandwidth shall not be less than two hertz (-3dB).

E.5.4 The maximum allowable unfiltered and filtered shaft vibration amplitude with the generator operating at rated voltage and frequency and at any load shall not exceed the limits shown in Figure E1 and Table E1.

TABLE E1
GENERATOR VIBRATION AMPLITUDES

Synchronous Speed (rpm)	Unfiltered Radial Shaft Displacement Peak-to-Peak (mils) See note 1	Filtered Radial Shaft Displacement Peak-to-Peak (mils) See notes 2, 3, 4
≤ 1200	3.0	2.5
1800	2.8	2.5
3600	2.0	1.8

Notes:

1. Includes allowances for maximum permissible probe-track runout (25% of the filtered limit).
2. Vectorially corrected for probe-track runout.
3. Vibration displacement at any filtered frequency below running-speed frequency shall not exceed 20% of the measured unfiltered vibration displacement.
4. Filtered (±1 Hz) vibration displacement at twice-line frequency (120 Hz for a 60 Hz system) or twice-running-speed frequency shall not exceed 0.5 mil peak-to-peak. This applies only to two-pole machines [E.5.7.2].

E.5.5 When specified, no-load vibration measurements shall be taken with rated voltage applied and recorded after the machine has run for at least 30 minutes and the bearing temperatures have stabilized to less than 1°C change between two successive readings 15 minutes apart. When noncontact probes or provisions for probes are specified, measurements shall include filtered amplitude (at 1/2X, 1X, and 2X running speed), filtered phase angle at 1X running speed, and unfiltered amplitude readings. Noncontact probe gap voltages (to within .01 VDC accuracy) shall be recorded every 15 minutes.

● **E.5.6** When a test run at rated temperature is specified, all vibration measurements shall be recorded every 30 minutes, along with minimum and maximum stator temperatures.

If the rated-temperature vibration displacement change from the no-load vibration exceeds 50% of the vibration limits of Paragraphs 5.3 and 5.4, while remaining under these vibration limits, the vibration test shall be repeated. This shall be done by letting the generator cool down and then be reloaded to achieve stable temperature with vibration being recorded. Succeeding "cold" machine and "hot" machine vibration displacement amplitudes shall reproduce the initial "cold" and "hot" values to within 15%. This test is intended to demonstrate the structural stability of the rotor.

E.5.7 Rotor response shall be determined by a plot of vibration amplitude and phase angle vs. speed, with the machine coasting down from 115 percent rated speed. The rotor shall be at magnetic center during the coastdown tests. These plots shall be taken of all shaft vibration probes following completion of the rated temperature run tests. Rotor resonances below operating speed shall be demonstrated. This test shall verify compliance with separation margin requirements of Section 2.5.2 of this specification. Rotor resonances shall not occur within the separation margin limits.

E.5.7.1 Rotor resonances within the separation margin limits (generators not meeting the separation margin requirements) shall be subjected to the tests described in E.5.7.1.1 and E.5.7.1.3 below to demonstrate a well-damped response. The specified separation margin or well-damped response shall be verified by attaching the assembled machine to a massive foundation [E.4.1] support and subjecting the generator to the following unbalance response test:

E.5.7.1.1 Apply a deliberate unbalance of four times the maximum allowable residual unbalance [E.3.2.4] per plane to the rotor. Place the weights at the location(s) which have the greatest affect on the vibrational mode. For translatory (static unbalance) modes, the appropriate weight placement is at both ends (e.g., on the fans) of the rotor and in phase. For conical (couple unbalance) modes, the weights are placed at both ends and 180 degrees out of phase. In cases where there is an overhung mass resulting in a bending mode with maximum deflections at the shaft end, the amount of unbal-

INSPECTION AND TESTING OF LARGE GENERATORS

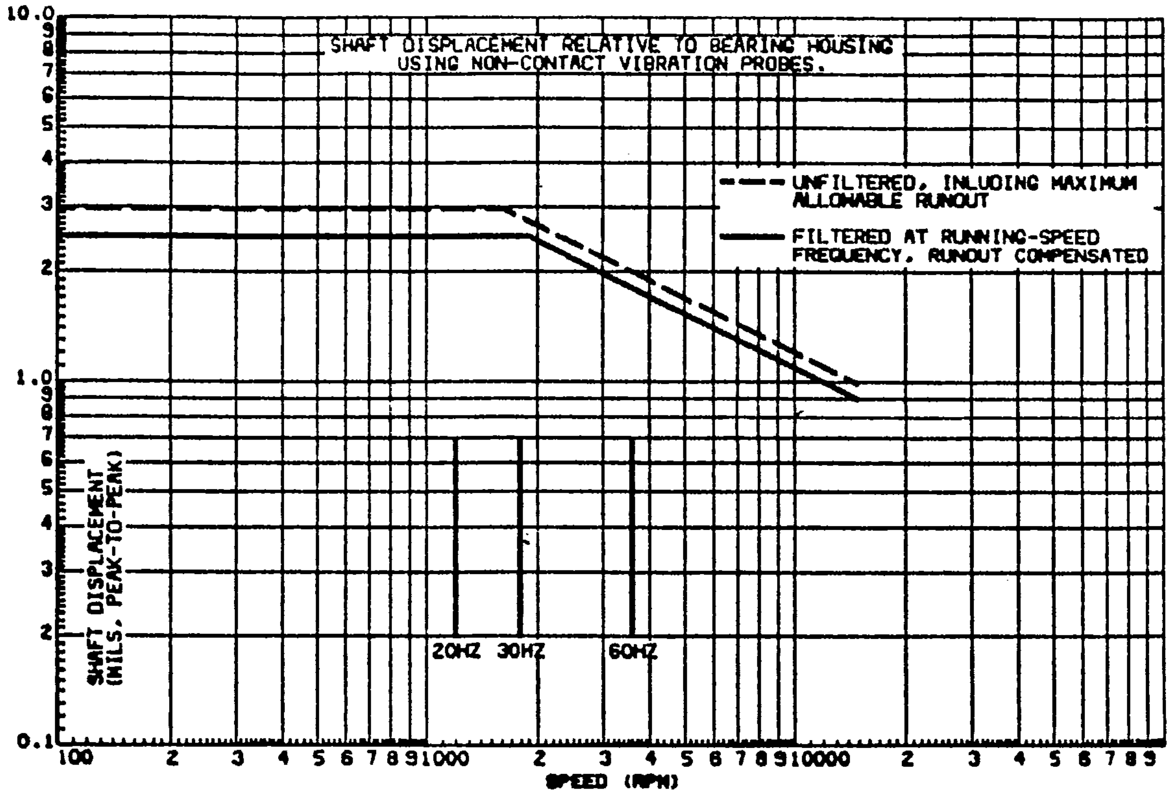


FIGURE E.1
SHAFT DISPLACEMENT LIMITS RELATIVE TO BEARING HOUSING

ance to be added to the exciter rotor or coupling is based on the overhung weight when applying the equation E.1 rather than journal static loading.

E.5.7.1.2 Run the generator to 115% of rated speed (with unbalance weights attached) and let it coast to rest. Observe the shaft vibration relative to the bearing housing. The following limits shall not be exceeded for generators with defined separation margins:

a. The shaft displacement relative to the bearing housing at any rated speed shall not exceed 150% of $(12{,}000/\text{rpm})^{1/2}$ (mils, peak- to-peak) or 55% of the minimum design shaft-to-bearing and seal diametral running clearance.

b. The shaft displacement relative to the bearing housing at any test speed shall not exceed 90% of minimum available design shaft-to-bearing diametral running clearance.

E.5.7.1.3 For a generator with no defined separation margin and for which a well-damped response is to be demonstrated, the generator shall be run to 115% of rated speed and let coast to rest with the deliberate unbalance described in E.5.7.1.2a. Shaft displacement relative to the bearing housing shall not exceed 150% of $(12{,}000/\text{rpm})^{1/2}$ (mils, peak-to-peak), where rpm is the rated speed. This limit applies to the entire speed range, zero to 115%.

E.5.7.2 For synchronous generators with excitation applied, the shaft vibration level filtered at twice-line frequency (120 Hz for 60 Hz power system), plus or minus two hertz, shall not rise more than 0.25 mil above the levels without power or excitation. For two pole synchronous generators, the maximum shaft vibration filtered at twice line frequency, ±2 Hz, shall not exceed 0.5 mil peak-to-peak.

E.6 Tests.

● **E.6.1 Electrical Tests.** When specified, all synchronous generators shall be tested in accordance with the applicable portions of NEMA MG 1.22.51, ANSI C50.10, C50.12, C50.13, C50.14 and IEEE 115. In addition, the following tests shall be made and results recorded:

E.6.1.1 Determination of open circuit saturation and core loss curve.

E.6.1.2 Determination of short circuit saturation and loss curve.

E.6.1.3 Measurement of main armature and field, and exciter armature and field insulation resistance per E.6.2.

E.6.1.4 Determination of efficiency at 1/2, 3/4, and full load using the segregated loss method of ANSI C50.10, 7.3, and NEMA MG 1.22.44. Losses shall be determined in accordance with IEEE 115, Separate-Drive Method (4.2), Electric-Input Method (4.3), or Retardation Method (4.4). Points for saturation curves shall also be recorded.

E.6.1.5 Determination of temperature rise of main armature and field at full-load or equivalent full-load conditions. The method of loading and readings taken shall be in accordance with IEEE 115, paragraphs 6.2.1, 6.2.2, or 6.2.3. An exciter heat run, or certified test data from a duplicate design, is also required.

E.6.1.6 Determination of telephone influence factor (TIF) per IEEE 115, 3.9, 3.10, and 3.11. TIF shall not exceed the limits of NEMA MG 1-22.43 and ANSI C50.10, 8.2, as applicable.

E.6.1.7 If two or more identical synchronous generators are purchased at the same time, items E.6.1.4, E.6.1.5 and E.6.1.6 of this section shall be determined for the first generator only. These tests are not required for the remaining identical units.

E.6.1.8 Generators shall be run at 25 percent overspeed for one minute, in accordance with IEEE 115 and NEMA MG 1-22.47. Cylindrical-rotor turbine driven generators shall be run at 20 percent overspeed for one minute in accordance with ANSI C50.12, C50.13, and C50.14. There shall be no permanent mechanical deformation.

E.6.2 Insulation Tests. After all running tests have been completed, the insulation of all generator windings, including the exciter and field windings shall be tested in accordance with the following:

E.6.2.1 All windings shall be given a high-potential test in accordance with NEMA MG1-22.52.

E.6.2.2 Following the high-potential test, insulation resistance of all windings shall be tested with a DC megohm tester. Test voltage shall be 1000 V for windings rated up to 600 V and 2500 V for windings rated over 600 V. The megohm test shall be maintained for ten minutes, with readings made at one-minute intervals, and the polarization index computed. The winding temperature shall be recorded.

E.6.2.3 Both the high-potential and insulation resistance test shall be conducted on one phase at a time, with the other two phases and all winding temperature detectors grounded, except where phase interconnections are permanently made within the stator.

E.6.2.4 Where insulated bearings are supplied, the insulation shall be tested using a high-range ohmmeter (applying approximately 20-30 VDC), with the ohmmeter test leads applied between the shaft and the frame.

E.6.3 Mechanical Running Tests.

● **E.6.3.1** When specified, the machine shall be warmed up to rated stator and rotor temperature rise by driving another machine as a generator (back to back or synchronous feedback), or by zero power factor loading in accordance with IEEE 115, 6.2.3 for synchronous machines.

E.6.3.2 For synchronous generators of a design where a rated-rotor current (i.e., generator "nameplate conditions" rotor current), short-circuited armature test can be run without exceeding the armature insulation class temperature rating, such a test shall be permitted to satisfy the rated-temperature test requirements of this section.

E.6.3.3 No-load (ambient temperature) running tests, when specified, shall be conducted for a minimum of one hour. Rated-temperature tests shall be conducted for a minimum of four hours and shall continue until there is not more than a 1°C change in stator temperature rise between two successive readings taken 30 minutes apart. Warming up machines by blocking ventilation openings is not acceptable.

E.6.3.4 Measurements shall be made at rated voltage, frequency, and temperature rise except where otherwise approved by the Purchaser in writing. The following tests and inspections shall be made during the no-load and load heat tests:

E.6.3.4.1 Vibration tests as specified in E.5.0. The vibration measurement procedure outlined in API 546, 2.4.7.3.3 shall be permitted, but peak vibration levels (as measured during a vibration modulation peak) shall not exceed the limits of E.5.0. If the generator must be stopped for temperature test resistance measurements, the generator shall be run again (full load) for at least 30 minutes after the resistance measurements have been made, and then the final vibration measurements shall be completed.

E.6.3.4.2 Bearing temperatures shall be recorded:

a. Bearing babbitt (white metal) temperatures shall not exceed the VENDOR specified normal temperature.

b. The temperature difference between bearings shall not exceed 10°C.

E.6.3.4.3 Inspect for internal and external oil leakage.

E.6.3.4.4 If any deviation from the specification or abnormal condition (such as oil leakage, or unusual noises) is noted during testing, the VENDOR shall correct the problem(s), and then retest the generator.

E.6.3.4.5 After all running tests have been completed, the shaft journals and bearings shall be inspected by completely removing both the top and bottom halves of each bearing. There shall be no measurable bearing-bore dimensional change or metal transfer between the shaft and bearing.

E.6.4 Electrical and Temperature Measurements. The following requirements shall apply to all tests on generators:

E.6.4.1 Current, voltage, and power in all three phases shall be measured and recorded for all running load tests.

E.6.4.2 All windings and bearing temperature measurements shall be made using permanently installed detectors, when purchased.

E.6.4.3 Unless specified otherwise, measurements of E.6.4.1 and E.6.4.2 shall be recorded every 30 minutes.

E.6.4.4 For machines with uninsulated bearings, a measurement of end-to-end shaft voltage shall be made with the generator operating at no load and rated voltage. Shaft voltage shall not exceed 0.2 volt rms.

E.6.5 Residual Magnetism.

E.6.5.1 After all testing has been completed, a set of residual magnetic field readings shall be made and recorded at the shaft end, journal, and seal areas. Readings shall be made with a flat transverse type "Hall" effect probe and gaussmeter.

E.6.5.2 Residual magnetism shall not exceed 3 gauss in the rotating and stationary interface areas such as the shaft journals and the bearing sleeves. Residual magnetism in the shaft extension and coupling areas shall not exceed 5 gauss. Magnetic fields exceeding these values will require demagnetizing to within acceptable levels prior to shipment.

E.6.5.3 Readings taken at abrupt geometric changes, such as shaft steps or shoulders, corners, holes, or keyways, are permitted to attain peak magnetic flux densities of twice the limits in E.6.5.2.

E.6.6 Miscellaneous Tests.

E.6.6.1 Where differential pressure switches are provided on enclosures with air filters, the switches shall be functionly tested and the set point shall be indicated on generator nameplate.

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