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

API STANDARD 616
FIFTH EDITION, JANUARY 2011

AMERICAN PETROLEUM INSTITUTE

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

Downstream Segment

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Foreword

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

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

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

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

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products (Sections 763.160-179).

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

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

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1 Scope

1.1 General

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

NOTE A bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. The information should be indicated on the datasheets (see Annex A); otherwise, it should be stated in the quotation request or in the order.

1.2 Alternative Designs

The vendor may offer alternative designs.

1.3 Conflicts

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

2 References

2.1 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *Manual of Petroleum Measurement Standards* (*MPMS*) Chapter 15:2001, *Guidelines for the Use of the International System of Units (SI)*

API Standard 541:2004, *Form-Wound Squirrel Cage Induction Motors—500 Horsepower and Larger*

API Standard 546:2008, *Brushless Synchronous Machines—500 KVA and Larger*

API Standard 547:2005, *General-Purpose Form-Wound Squirrel Cage Induction Motors—250 Horsepower and Larger*

API Standard 611:2008, *General-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

API Standard 612:2005, *Special-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

API Standard 613:2003, *Special-Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services*

API Standard 614:2008, *Lubrication, Shaft-Sealing, and Oil-control Systems and Auxiliaries*

API Standard 670:2000, *Machinery Protection Systems*

API Standard 671:2007, *Special-Purpose Couplings for Petroleum, Chemical and Gas Industry Services*

API Standard 677:2006, *General-Purpose Gear Units for Petroleum, Chemical and Gas Industry*

API Recommended Practice 684:2005, *API Standard Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals, and Rotor Balancing*

API Recommended Practice 686:2009, *Recommended Practices for Machinery Installation and Installation Design*

API Recommended Practice 687:2001, *Rotor Repair*

ABMA Standard 11:1990 [1], *Load Ratings and Fatigue Life for Roller Bearings*

ABMA Standard 7:1995, *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*

ABMA Standard 9:1990, *Load Ratings and Fatigue Life for Ball Bearings*

AGMA 6123-B06:2006 [2], *Design Manual for Enclosed Epicyclic Gear Drives*

ASM [3], AISI 1020:1982, *Case Hardening and General Purpose Steel*

ASME B1.1:2003 [4], *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B1.20.1:2006, *Pipe Threads, General Purpose (Inch)*

ASME B16.1:2005, *Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250*

ASME B16.5:2003, *Pipe Flanges and Flanged Fittings*

ASME B16.11:2005, *Forged Steel Fittings, Socket Welded and Threaded*

ASME B16.42:2006, *Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300*

ASME B16.47:2006, *Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard*

ASME B31.3:2006, *Process Piping*

ASME B46.1:2002, *Surface Texture, Surface Roughness Waviness and Lay*

ASME B133.8:2001, *Gas Turbine Installation Sound Emissions*

ASME PTC 1:2004, *General Instructions*

ASME PTC 22:2006, *Performance Test Code on Gas Turbines*

ASME Y14.2M: 2003, *Line Conventions and Lettering*

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section V: Nondestructive Examination*

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[1] American Bearing Manufacturers Association, 2025 M Street, NW, Suite 800, Washington, DC 20036, www.abma-dc.org.
[2] American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, www.agma.org.
[3] ASM International, 9636 Kinsman Road, Materials Park, Ohio 44073, www.asminternational.org.
[4] ASME International, Three Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section VII: Pressure Vessels*

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section VIII: Rules for Construction of Pressure Vessels*

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section IX: Welding and Brazing Qualifications*

ASTM A123/A123M:2009 [5], *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

ASTM A193/A193M:2009, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194/A194M:2009, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A247:2006, *Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings*

ASTM A278/A278*M:2006, Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650 °F (350 °C)*

ASTM A307:2007, *Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*

ASTM A320/A320M:2008, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature*

ASTM A388/A388M:2009, *Standard Practice for Ultrasonic Examination of Steel Forgings*

ASTM A395/A395M:2009, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM A515/A515M:2007, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

ASTM A516/A516M:2006, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM A536:2009, *Standard Specification for Ductile Iron Castings*

ASTM A563:2007, *Standard Specification for Carbons and Alloy Steel Nuts*

ASTM A578/A578M:2007, *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*

ASTM A609/A609M:2007, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

ASTM A1011/A1011M:2009a, *Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength*

ASTM D1655:2009, *Standard Specification for Aviation Turbine Fuels*

ASTM D2880:2003, *Standard Specification for Gas Turbine Fuel Oils*

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[5] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E94:2004, *Standard Guides for Radiographic Testing*

ASTM E165:2009, *Standard Test Method for Liquid Penetrant Examination for General Industry*

ASTM E709:2008, *Standard Guides for Magnetic Particle Examination*

AWS D1.1:2006 [6], *Structural Welding Code Steel*

CSA C22.1-06 [7], *Canadian Electrical Code, Part I (20th Edition), Safety Standard for Electrical Installations, Includes Update No. 1*

EN 287-1:2004 [8], *Qualification test of welders. Fusion welding. Steels*

EN 288-9:1999, *Specification and approval of welding procedures for metallic materials. Welding procedure test for pipeline welding on land and offshore site butt welding of transmission pipelines*

EN 614-1:2006, *Safety of machinery. Ergonomic design principles. Terminology and general principles*

EN 779:2002, *Particulate air filters for general ventilation: Determination of filtration performance*

EN 1822:1998, *High efficiency air filters (HEPA and ULPA). Classification, performance testing, marking*

European Directive, 94/9/EC:2009 [9], *Equipment intended for use in potentially explosive atmosphere*s, Third Edition

IEC 60034-1:2004 [10], *Rotating electrical machines—Part 1: Rating and performance,* 11th Edition

IEC 60079-0:2007, *Explosive atmospheres*, Fifth Edition

IEC 60204-1:2005, *Safety of machinery—electrical equipment of machines—Part 1: General requirements*, Edition 5.0 b

IEC 60529:2001, *Degrees of protection provided by enclosures (IP code)*

IEC 61779-1:1998, *Electrical apparatus for the detection and measurement of flammable gases – Part 1: General requirements and test methods*, Edition 1.0

IEEE 841:2009 [11], *Standard for the Petroleum and Chemical Industry—Premium-Efficiency, Severe-Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp)*

ISO 7-1:1994 [12], *Pipe threads where pressure-tight joints are made on the threads*

ISO 261:1998, *General purpose metric screw threads—general plan*

ISO 281:2007, *Rolling bearings—dynamic load ratings and rating life*

ISO 1461:2009, *Hot dip galvanized coatings on fabricated iron and steel articles—specifications and test methods*

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[6] American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.
[7] Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, L4W 5N6, Canada, www.csa.ca.
[8] European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.
[9] European Commission, Enterprise and Industry DG, B-1049, Brussels, Belgium, www.ec.europa.eu,
[10] International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.
[11] Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, www.ieee.org.
[12] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

ISO 1940-1:2003, *Mechanical vibration—balance quality requirements for rotors in a constant (rigid) state—Part 1: Specification and verification of balance tolerances*

ISO 2314:1989, *Gas turbines—acceptance tests*

ISO 3448:1992, *Industrial liquid lubricants—ISO viscosity classification*

ISO 3744-1994, *Acoustics—determination of sound power levels of noise sources using sound pressure—engineering method in an essentially free field over a reflecting plane*

ISO 6183:2009, *Fire protection equipment—carbon dioxide extinguishing systems for use on premises—design and installation*

ISO 6708-1995, *Pipework components—definition and selection of DN (nominal size)*

ISO 7005-1:1992, *Metallic flanges—Part 1: Steel flanges*

ISO 7005-2:1998, *Metallic flanges—Part 2: Cast iron flanges*

ISO 7919-1:1996, *Mechanical vibration of non-reciprocating machines—measurements on rotating shafts and evaluation criteria—Part 1: General guidelines*

ISO 7919-4:2009, *Mechanical vibration of non-reciprocating machines—measurements on rotating shafts and evaluation criteria—Part 4: Gas turbine sets*

ISO 8068:2006, *Lubricants, industrial oils and related products (class L)—Family T (Turbines)—Specification for lubricating oils for turbines*

ISO 8501:2007, *Preparation of steel substrates before application of paints and related products—visual assessment of surface cleanliness*

ISO 8821:1989, *Mechanical vibration—balancing—shaft and fitment key convention*

ISO 10438:2007, *Petroleum, petrochemical and natural gas industries—lubrication, shaft-sealing and control-oil systems and auxiliaries*

ISO 10441:2007, *Petroleum, petrochemical and natural gas industries—flexible couplings for mechanical power transmission—special-purpose applications*

ISO 10494:1993, *Gas turbines and gas turbine sets—measurement of emitted airborne noise—engineering/survey method*

ISO 10816-1:1995, *Mechanical vibration—evaluation of machine vibration by measurements on non-rotating parts—Part 1: General guidelines*

ISO 10816-4:2009, *Mechanical vibration—evaluation of machine vibration by measurements on non-rotating parts—Part 4: Gas turbine driven sets with fluid-film bearings*

ISO 11342:1998, *Mechanical vibration—methods and criteria for the mechanical balancing of flexible rotors*

ISO 13387-7:1999, *Fire safety engineering—Part 7: Detection, activation, and suppression*

ISO 13732:2006, *Ergonomics of the thermal environment—methods for the assessment of human responses to contact with surfaces*

ISO 14123-1:1998, *Safety of machinery—reduction of risks to health from hazardous substances emitted by machinery—Part 1: Principles and specifications for machinery manufacturers*

ISO 14520:2005/6, *Gaseous fire-extinguishing systems—physical properties and system design*

ISO 14691:2008, *Petroleum, petrochemical, and natural gas industries—flexible couplings for mechanical power transmission—general-purpose applications*

ISO 15614:2008, *Specification and qualification of welding procedures for metallic materials—welding procedure test*

ISO 19499:2007, *Mechanical vibration—balancing—guidance on the use and application of balancing standards*

ISO 21789:2009, *Gas turbine applications—safety*

MIL-E-5007:RevD [13], *General Specification for Engine, Aircraft, TurboJet, and TurboFan*

MIL-S-8879:1991, *Screw Thread Standard, Controlled Radius Root with Increased Minor Diameter, General Specification*

NACE [14], *NACE Corrosion Engineer's Handbook*

NACE MR 0175:2003, *Petroleum and Natural Gas Industries—Materials for Use in* H_2S*-Containing Environments in Oil and Gas Production*

NEMA 250: 2003 [15], *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NFPA 12:2008 [16], *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 70:2008, *National Electrical Code*

NFPA 750:2006, *Standard on Water Mist Fire Protection Systems*

NFPA 2001:2008, *Standard on Clean Agent Fire Extinguishing Systems*

SAE B92.1:1996 [17], *Involute Splines and Inspection*

SAE J514:2004, *Hydraulic Tube Fittings*

SSPC SP6:2000 [18], *Commercial Blast Cleaning—NACE No. 3:2000*

2.2 Compliance

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

2.3 Responsibilities

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

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[13] U.S. Department of Defense, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, Pennsylvania 19111-5094, http://assist.daps.dla.mil.
[14] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
[15] National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.
[16] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
[17] Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.
[18] The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburg, Pennsylvania 15222, www.sspc.org.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following terms, definitions, acronyms, abbreviations, and symbols apply.

3.1
alarm point
Preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action.

DISCUSSION All alarm points have to be measured however all measured points do not have to be alarmed.

3.2
anchor bolts
Bolts used to attach the equipment to the support structure (concrete foundation or steel structure). [See **hold-down bolt** (3.14).]

3.3
axially split joint
Joint split with the principal face parallel to the shaft centerline.

3.4
blade lock-up speed
Speed of rotation at which a part span or tip damping device (whether joining all or multiple numbers of individual blades) becomes effective.

3.5
blades
Rotating air foils for both compressors and turbines unless modified by an adjective.

3.6
critical speed
Shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.7
design
Manufacturer’s calculated parameter.

NOTE A term used by the equipment manufacturer to describe various parameters such as design power, design pressure, design temperature, or design speed. It is not intended for the purchaser to use this term.

3.8
diamètre nominal or **nominal diameter**
DN
Alphanumeric designation of size for components of a pipework system. [See **nominal pipe size (NPS)** (3.30).]

EXAMPLE DN 20.

NOTE 1 Adapted from ISO 6708:1995.

NOTE 2 The letters DN are followed by a dimensionless whole number which is indirectly related to the physical size, in millimeters, of the bore or outside diameter of the end connection. Table 1 lists the corresponding DN and NPS pipe sizes.

NOTE 3 The number following the letters DN does not represent a measurable value.

NOTE 4 In those standards which use the DN designation system, any relationship between DN and component dimensions should be given, e.g., DN/OD or DN/ID [ISO 6708:1995 (E)].

Table 1—Corresponding DN and NPS Pipe Sizes

Diameter Nominal (DN) mm	**Nominal Pipe Size (NPS)** in.
6	$^1/_8$
8	$^1/_4$
10	$^3/_8$
15	$^1/_2$
20	$^3/_4$
25	1
32	$1^1/_4$
40	$1^1/_2$
50	2
65	$2^1/_2$
80	3
100	4
150	6
200	8
250	10
300	12
350	14
400	16
450	18
500	20
550	22
600	24
650	26
700	28
750	30
800	32
900	36
1000	40
1100	42
1200	48
1400	54
1500	60
1600	64
1800	72
2000	80
2200	88

NOTE 1 Up to and including 12-in. diameter piping, the bore is the nominal dimension of the pipe. Above 12-in. pipe, the OD is the nominal dimension of the pipe.

NOTE 2 The thickness of the pipe is determined by specifying the pipe schedule.

3.9
filter stage
Section of a filter system which is designed to remove specific site contaminants at a prescribed efficiency and pressure drop.

NOTE A stage may be a specific medium, a mist eliminator, or a self-cleaning section. Multistage filters are combinations of various filters. Weather hoods and screens are not considered stages.

3.10
flat rating
Practice of limiting the gas turbine engine power to a constant level over the entire operating ambient temperature range.

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

3.11
gas generator
Device in which only energy required to drive the compressor stages and auxiliaries is extracted from discharging gas by the turbine stages.

3.12
gauge board
Bracket or plate used to support and display gauges, switches and other instruments. [See **panel** (3.40).]

NOTE A gauge board is not a panel. A gauge board is open and not enclosed. A panel is an enclosure.

3.13
heat rate
Energy consumption of a prime mover per unit of output work.

NOTE For gas turbines, the heat rate is calculated on the basis of the lower heating value of the fuel.

3.14
hold-down bolts or **mounting bolts**
Bolts holding the equipment to the mounting plate.

3.15
hydrodynamic bearings
Bearings that use the principles of hydrodynamic lubrication.

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

3.16
informative
Information only. [See **normative** (3.34).]

NOTE An informative reference or annex provides advisory or explanatory information. It is intended to assist the understanding or use of the document.

3.17
inlet volume flow
Flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility and gas composition, including moisture content, at the compressor inlet flange.

NOTE Inlet volume flow is a specific example of actual volume flow. Actual volume flow is the volume flow at any particular location such as interstage, impeller inlet, discharge, or compressor discharge. Actual volume flow should not be used interchangeably therefore with inlet volume flow.

3.18
ISO-rated cycle temperature
Vendor's stated (calculated) turbine inlet total temperature, immediately upstream of the first-stage turbine rotor blades, for continuous service at ISO-rated power output.

3.19
ISO-rated firing temperature
Vendor's stated (calculated) turbine inlet total temperature, immediately upstream of the first-stage turbine nozzles, for continuous service at ISO-rated power output.

3.20
ISO-rated power
Continuous power developed by the gas turbine when it is operated at ISO-rated firing temperature and speed under the following standard operating conditions (see ISO 2314):

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

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

3.21
local
<Position of devices> on or near the equipment or console.

3.22
maximum allowable speed
Highest speed at which the manufacturer's design will permit intermittent operation for overspeed and testing transients.

The maximum allowable speed is used to establish a trip speed for train components (see 5.1.1.9) or to establish a speed above the maximum continuous speed for testing (see 6.3.4.2.2).

3.23
maximum allowable temperature
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

3.24
maximum allowable working pressure
MAWP
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 maximum operating temperature.

3.25
maximum continuous speed
Highest rotational turbine output shaft speed (revolutions per minute) at least equal to the 105 % of the rated speed.

3.26
maximum exhaust pressure
Highest exhaust pressure at which the turbine is required to operate continuously.

3.27
minimum allowable speed
Lowest turbine output shaft speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

NOTE Minimum allowable speed can be set by many factors. These may include, but are not limited to, the following: location of critical speeds (lateral and torsional), blade natural frequencies, minimum differentials which need to be developed across close clearances for lubrication, cooling, rotordynamic damping and stiffening, and minimum speed of shaft driven lubricating pumps.

3.28
minimum allowable temperature
Lowest temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

3.29
mounting plate
Device used to attach equipment to concrete foundations; includes both baseplates and soleplates.

3.30
nominal pipe size
NPS
Dimensionless value approximately equal to the diameter in inches [See **diamètre nominal** or **nominal diameter (DN)** (3.8).]

EXAMPLE NPS $^3/_4$.

NOTE 1 Adapted from ASME B31.3:2006, Paragraph 300.2.

NOTE 2 The letters NPS are followed by a dimensionless number which is related to the physical size, in inches of the bore or outside diameter of the pipe.

NOTE 3 The number following the letters NPS does not represent a measurable value.

NOTE 4 NPS is a designation of pipe size only. The pipe end may be threaded or prepared for a welded fitting.

NOTE 5 Up to and including 12-in. diameter piping, the bore is the nominal dimension of the pipe, above 12-in. pipe, the OD is the nominal dimension of the pipe.

NOTE 6 The thickness of the pipe is determined by specifying the pipe schedule.

3.31
normal operating point
Point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies the heat rate is within the tolerances stated in this standard (see 4.1.3).

NOTE Parameters used to determine the normal operating point include speed, site conditions, emissions and fuel composition.

3.32
normally open or **normally closed**
<On-the-shelf> state of a device (e.g. automatically activated switch or actuated valve).

NOTE 1 The following table (Table 2) gives examples of various devices and their on-the-shelf state.

Table 2—Various Devices and "On-the-Shelf State"

Device	On-the-shelf State
electrically activated devices	deenergized position of the device
automatically activated pressure switch	state of the contacts at ambient pressure
flow switch	state of the contacts at no flow
level switch	state of the contacts at no level
limit switch	state of the contacts at nonactuated condition
speed switch	state of the contacts at 0 revolutions per minute

NOTE 2 During operation of the equipment, these devices may be normally energized or actuated, therefore, the state of these devices during operation may not be the same as their on-the-shelf state.

3.33
normally open or **normally closed**
<Manual hand valve> state during normal operation.

3.34
normative
Required. [See **informative** (3.16).]

NOTE A normative reference or annex enumerates a requirement or mandate of the specification.

3.35
nozzles (fixed and variable)
Turbine stationary (nonrotating) airfoils.

3.36
NPT
American National Standard Pipe Taper thread form designation for pipe threads.

EXAMPLE NPT $^{3}/_{4}$ – 14

NOTE 1 It is comprised of a number representing nominal pipe size followed by the number of threads per inch and the letters NPT representing the thread series.

NOTE 2 Pipe size and number of threads per inch may be found in ASME B.1.20.1:2006, Table 2, a section of which has been reproduced for reference below in Table 3.

Table 3—Pipe Size and Number of Threads per Inch

Nominal Pipe Size	OD of Pipe (D)	Threads per inch (n)
1	2	3
1/16	0.3125	27
1/8	0.405	27
1/4	0.540	18
3/8	0.675	18
1/2	0.840	14
3/4	1.050	14
1	1.315	11.5
1 1/4	1.660	11.5
1 1/2	1.900	11.5
2	2.375	11.5
2 1/2	2.875	8
3	3.500	8
3 1/2	4.000	8
4	4.500	8
5	5.563	8
6	6.625	8
8	8.625	8
10	10.750	8
12	12.750	8
14 OD	14.000	8
16 OD	16.000	8
18 OD	18.000	8
20 OD	20.000	8
24 OD	24.000	8

3.37
observed
Inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled, with or without the purchaser or his representative present.

3.38
open cycle
One which the working medium enters the gas turbine from the atmosphere and discharges to the atmosphere directly or indirectly through exhaust heat recovery equipment

NOTE When the working medium only passes successively through the compressor, the combustor and the turbine and is discharged directly into the atmosphere, it is called a simple cycle. When turbine exhaust is used to preheat (by exchange) combustion air from the compressor, it is called a regenerative cycle.

3.39
owner
Final recipient of the equipment who may delegate another agent as the purchaser of the equipment.

3.40
panel
Enclosure used to mount, display and protect gauges, switches and other instruments.

3.41
potential maximum power
Expected power capability when the gas turbine is operated at maximum allowable firing temperature, rated speed or under other limiting conditions as defined by the manufacturer and within the range of specified site values.

3.42
power turbine
Turbine having a separate shaft from which output power is derived.

3.43
pressure casing
Composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

3.44
purchaser
Agency that issues the order and specification to the vendor.

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

3.45
$\mathbf{R_a}$
Arithmetical average of the absolute value of the profile height deviations recorded within the evaluation length and measured from the mean line.

NOTE 1 Adapted from ASME B46.1:2002, Paragraph 1.4.1.1.

NOTE 2 It is the average variation in height of the entire surface, within the sampling length, from the mean line.

3.46
radially split
Split with the principal joint perpendicular to the shaft centerline.

3.47
rated speed/100 % speed (mechanical drive applications)
Highest speed (revolutions per minute) of the gas turbine output shaft required of any of the operating conditions for the driven equipment and at which site rated power is developed.

3.48
rated speed/100 % speed (generator drive applications)

Speed (revolutions per minute) of the gas turbine output shaft required for synchronous generator speed and at which the site rated power is developed.

3.49
relief valve set pressure
Pressure at which a relief valve starts to lift.

3.50
remote
Location of a device when located away from the equipment or console, typically in a control room.

3.51
shutdown set point
Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.52
site rated conditions
Purchaser-specified values at the inlet to the air filter of the maximum inlet air temperature and minimum inlet air pressure at which site rated power is required.

Inlet and exhaust ducting and other facilities, barometric variations and ambient temperature ranges shall be considered when specifying the site rated conditions.

3.53
site rated cycle temperature

Turbine inlet total temperature, immediately upstream of the first-stage turbine rotor blades, required to meet site rated power.

3.54
site rated firing temperature
Turbine inlet total temperature, measured at a location immediately upstream of the first-stage turbine nozzles, required to meet site rated power.

3.55
site rated power
Shaft power developed by the gas turbine when it is operated at site rated firing temperature, rated speed and site rated conditions of inlet temperature, inlet pressure, exhaust pressure, and normal fuel composition.

3.56
special tool
Tool which is not a commercially available catalog item.

3.57
standard volume flow
Flow rate expressed in volume flow units at standard conditions as follows:

ISO Standard Conditions

Flow:	Cubic meters per hour (m^3/hr)
	Cubic meters per minute (m^3/min)
Pressure:	1.013 bar
Temperature:	15 °C

U.S. Standard Conditions

Flow:	Standard cubic feet per minute (scfm)
	Million standard cubic feet per day (mmscfd)
Pressure:	14.7 psi
Temperature:	60 °F

3.58
standby
Service state in which a piece of equipment is normally idle or idling and is capable of immediate automatic or manual start-up for continuous operation.

3.59
thermal efficiency
Ratio of the energy output at the power turbine shaft (or generator terminals) to the energy input (based on the lower heating value of the fuel) expressed in the same units.

External auxiliaries not directly driven are not included in parasitic losses.

3.60
total indicator reading or **total indicated runout**
TIR
Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

NOTE For a cylindrical surface, the indicated runout implies an eccentricity equal to half the reading. For a flat face, the indicated runout implies an out-of-squareness equal to the reading. If the diameter in question is not cylindrical or flat, the interpretation of the meaning of TIR is more complex and may represent ovality or surface irregularities.

3.61
trip speed
Turbine speed at which the independent emergency overspeed device shuts off fuel to the gas turbine.

3.62
unit responsibility
Obligation for coordinating the documentation, delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

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

3.63
vanes (fixed and variable)
Compressor stationary (nonrotating) airfoils.

3.64
vendor or **supplier**
Manufacturer or manufacturer's agent that supplies the equipment.

3.65
witnessed
Inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or the purchaser's representative is in attendance.

4 Basic Design

4.1 General

4.1.1 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least three years of uninterrupted operation. It is recognized that this is a design criterion and that hot section inspections (see Annex E) may be required; however, the required time between inspections shall be no less than 8000 operating hours. The 8000-hour requirement applies to base-loaded machines using sweet, dry gas fuel that meets manufacturer's specifications. The vendor shall supply the service life and minimum uninterrupted operation interval based on each specific application. The maintenance procedure necessary to achieve these intervals shall also be supplied. For aeroderivative gas turbines, the time required for intrusive (requiring parts removal) inspections shall be no less than 12,000 operating hours. Nonintrusive inspections, e.g. those requiring the use of a boroscope may be more frequent as required by the manufacturer.

NOTE Auxiliary system design and design of the process in which the equipment is installed are very important criteria in meeting this objective.

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

• **4.1.3** The purchaser will specify the equipment's normal operating point on the datasheets (see 3.31 and Annex A).

4.1.3.1 The gas turbine vendor shall provide turbine full load power (with no negative tolerance) at the normal duty point condition as shown on the datasheet with a 3 % tolerance on the heat rate (lower heating value for normal fuel).

4.1.3.2 Turbine power and heat rate shall be proven by factory testing. When factory testing is not practical, field testing (under the supervision of the turbine vendor) is acceptable using agreed upon power and heat rate tolerances.

4.1.4 Gas turbine units shall be suitable for shutdown periods of up to three weeks, under specified site conditions (see 4.1.19), without requiring any special maintenance procedures. Some manufacturers require some portion of their auxiliary systems to remain in service during shutdown periods, for instance, heating elements in frigid climates.

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

NOTE Electrical generator drive gas turbines are typically limited to a much tighter speed range due to generator restrictions. This speed range is typically 95 % to 105 % of rated speed.

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

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

• **4.1.8** The purchaser will specify the maximum allowable emissions levels at the package boundaries. The control of exhaust emissions levels of the package shall be a joint effort of the gas turbine vendor and the purchaser. Any restrictions on the gas turbine's speed or load range related to emission control shall be stated in the proposal. It is the responsibility of the purchaser to obtain any permits that may be required to operate the equipment and it is the responsibility of the gas turbine vendor to support the purchaser with emissions data. The gas turbine vendor shall state in his proposal expected emissions levels consistent with the purchaser's specified fuel properties (see 5.8.2.1

or 5.8.4.3) and site operating conditions (see 4.1.19). The gas turbine vendor shall supply, if required, the gas turbine combustion emission suppression system to meet the specified levels of NO_x, CO, and unburned hydrocarbons in the gas turbine's exhaust gas. Any restrictions on the speed range or load range of units with emission control shall be stated in the proposal.

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

• **4.1.10** Limiting and attenuation of the sound pressure level (SPL) of all equipment furnished shall be the responsibility of the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified by the purchaser and measured in accordance with ISO 10494 or ASME B133.8. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for each principal component supplied.

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

— water velocity over heat exchange: 1.5 m/s to 2.5 m/s, 5 ft/s to 8 ft/s;

— maximum allowable working pressure: >7.0 bar (see Note 1), >100 psig;

— hydrotest pressure (1.5 × MAWP): ≥10.5 bar (see Note 1), ≥150 psig;

— maximum pressure drop: 1 bar, 15 psi;

— maximum inlet temperature: 30 °C, 90 °F;

— maximum outlet temperature: 50 °C, 120 °F;

— maximum temperature rise: 20 K, 36 °F;

— minimum temperature rise: 10 K, 18 °F;

— fouling factor on water side: 0.35 m^2 K/kW, 0.002 hr-ft^2-°F/Btu;

— water side corrosion allowance: 3 mm, $^1/_8$ in.

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

NOTE 1 Gauge pressure.

NOTE 2 Refer to API *MPMS* for guidelines for the use of the International system of units (SI).

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

4.1.13 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. Pre-engineered packages with prearranged piping and equipment may be offered. The arrangement shall be submitted to the purchaser for review and specific purchaser requirements discussed during the offer phase. The arrangement of enclosure piping and conduits shall provide adequate clearance areas and safe access for operation and maintenance and shall not cause a maintenance obstruction.

● **4.1.14** Motors, electrical components, and electrical installations shall be suitable for the area classification specified (class, group, and division or zone). The applicable electrical codes are specified in 5.4.1.5.3.

NOTE Electrical devices on aeroderivative gas turbines are typically designed in accordance with aircraft explosion-proof requirements of MIL-E-5007, which generally meets the requirements of Class 1, Group D, Division 2.

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

4.1.16 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or cylindrically doweled) and manufactured to ensure accurate alignment on reassembly. Vanes and nozzles, seals, and rotating elements shall be replaceable on site. The package design shall incorporate lifting devices for all normal maintenance activities. The vendor's proposal shall describe the special tooling, including lifting and support devices, needed for on-site repair or replacement of parts. If the design requires field disassembly, the vendor shall state in the proposal the procedure for the disassembly required for such repair or replacement of parts. The vendor's proposal shall state the duration of the maintenance activities and the number of people required to perform the work.

NOTE For small frame-type or aeroderivative gas turbines, it is not unusual to remove the entire engine or a major component such as the gas generator or power turbine and perform all disassembly work in a shop equipped to service the equipment.

● **4.1.17** The gas turbine and its driven equipment shall perform on the test stand(s) and on their permanent foundation within the agreed acceptance criteria. If specified, after installation at the site, the performance of the combined units shall be verified. The testing protocol and acceptance criteria are the joint responsibility of the purchaser and the vendor that has unit responsibility.

NOTE Field acceptance criteria can be different than test stand acceptance criteria. Details of the field acceptance are mutually agreed between the purchaser and vendor.

4.1.18 Many factors (such as piping and duct loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) can adversely affect site performance. To minimize the influence of these factors, the vendor shall provide the maximum acceptable load data at each interface point. Particular attention should be given to any changes in piping alignment when major flanges of the equipment are unfastened. If specified, the vendor's representative shall:

● a) review and comment on the purchaser's ducting layout, piping systems, and foundations drawings;

● b) observe a check of the major piping connections by parting the flanges;

● c) check alignment at the operating temperature;

● d) witness the initial alignment check.

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

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

4.1.21 The gas turbine shall be designed to provide site rated power with no negative tolerance in the new and un-fouled condition.

• **4.1.22** The purchaser shall specify the pressure, temperature and flow for bleed air utilized outside the gas turbine. The vendor shall specify in the proposal the quantity, extraction stage, and pressure available for use by the purchaser. Bleed air shall not be extracted from sealing or cooling air lines.

4.1.23 Vendor shall supply quantity, extraction stage, and pressure for each internal gas turbine cooling air stream. The vendor shall specify the requirement for utility air from the purchaser.

4.2 Pressure Casings

4.2.1 The hoop-stress values used in the design of the casing shall not exceed the maximum allowable stress values in tension specified in Section VIII, Division 2 of the ASME Code at the maximum operating temperature of the material used. Aeroderivative gas turbine casings are manufactured to recognized codes of the aircraft industry which may not agree with all ASME requirements.

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

4.2.3 Either radially or axially split casings are acceptable depending on the vendor's standard. The vendor's proposal shall clearly show the extent of component removal required for site maintenance. All casing joints, except inlet and exhaust flange connections, shall be metal fits without gaskets. All casing joints shall be tight at operating pressure and temperature with minimum perceptible leakage. Minimum perceptible leakage shall be such that it poses no health issues to personnel adjacent to the joint, no impact to performance of the gas turbine, no damage to the instrumentation near the joint, nor influence the heat detection system associated with fire protection inside the gas turbine enclosure.

4.2.4 Casings, supports, and baseplates shall be designed to prevent any injurious distortion that could be caused by the worst combination of allowable temperature, pressure, torque, and external forces and moments. Casings shall be designed or suitable guarding shall be provided to contain all blade-off events and the subsequent collateral damage, but not disk burst or overhung shaft failure. Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews. The unit design shall also minimize the output shaft displacement between hot and cold positions.

NOTE Many aeroderivative gas turbines are mounted by adjustable links.

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

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

4.2.7 Bolting shall be furnished as specified in 4.2.7.1 through 4.2.7.4.

• **4.2.7.1** The threading shall conform to ISO 261 (metric) or ASME/ANSI B1.1 (inch series) as specified.

NOTE On aeroderivative gas turbines, the use of bolts meeting MIL-S-8879 is acceptable.

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

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

NOTE For limited space locations, integrally flanged fasteners are acceptable.

4.2.7.4 Manufacturer's marking shall be located on all fasteners 6 mm ($^1/_4$ in.) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

NOTE A set screw is a headless screw with an internal hex opening on one end.

4.2.8 Openings for inspection instruments such as boroscopes shall be provided to permit complete inspection of all rotating air and hot gas-path components without disassembly. The inspection ports shall be marked for identification purposes. In the case where physical space constraints do not permit the complete inspection of all rotating air and hot gas path components by boroscope, the vendor shall describe in the proposal the extent of inspection achievable.

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

4.2.10 For manufacturers unable to comply with the full speed testing requirements of this standard, see 6.3.5.2, the ducting, rotor and casing design shall permit field balancing in the end planes of the rotors without requiring the removal of major casing components. Balancing by adding weights to couplings is prohibited. Some multishaft gas turbines might not have both rotors accessible without major component removal. In this case, the vendor must indicate which shaft is not accessible and how the vendor expects to complete any field balancing.

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

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

4.3 Combustors and Fuel Nozzles

4.3.1 All combustor systems shall be provided with dual ignition. Combustor systems without cross-ignition tubes shall be provided with two igniters in each combustor.

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

NOTE In aeroderivative gas turbine designs, the sensors are located in the combustors, down stream of the last compressor stage and in the inlet to the power turbine.

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

NOTE Some dry low NO_x aeroderivative gas turbines require removal of the combustor to access and service the fuel nozzles.

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

4.3.5 Normally, igniters shall not remain in the primary combustion zone during operation.

NOTE Annular combustors allow the ignitor to be located in the combustor during operation.

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

4.3.7 The manufacturer shall indicate the capabilities of the proposed combustion system by advising maximum and minimum and the maximum allowable rate of change of the Wobbe index.

4.4 Casing Connections

● **4.4.1** Air inlet and exhaust connections of the pressure casings shall be flanged or machined and studded, oriented as specified and suitable for the positive or negative working pressure of the casing as defined in 3.24.

4.4.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values and temperature-pressure rating, rather than the requirements of the connected piping (see 4.10.4.7). All welding of connections shall be completed before the casing is hydrostatically tested.

4.4.3 Casing openings for piping connections shall be at least DN 20 (NPS $^{3}/_{4}$) and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes DN 20 (NPS $^{3}/_{4}$) through DN 40 (NPS $1^{1}/_{2}$) are permissible. The pipe nipples installed in the threaded openings shall be as specified in 4.4.3.1 through 4.4.3.5.

NOTE On aeroderivative gas turbines, flanges and tubing according to aircraft industry standards are acceptable.

4.4.3.1 Pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS $1^{1}/_{2}$).

4.4.3.2 The pipe nipple shall be provided with a welding-neck or socket-weld flange.

4.4.3.3 The nipple and flange materials shall meet the requirements of 4.4.2.

4.4.3.4 Bosses for pipe threads shall conform to ASME B16.5.

● **4.4.3.4.1** Threaded openings and bosses for tapered pipe threads shall conform to ISO 7- l: 1994 and 7005-2:1988 or ASME B1.20.1 as specified.

● **4.4.3.4.2** If ISO 7-1:1994 has been specified, tapered or straight internal threads shall also be specified.

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

4.4.5 Flanges shall conform to ASME B16.1, ASTM B16.5, or ASTM B16.42 as applicable, except as specified in 4.4.5.1 through 4.4.5.3. Internal package piping shall use similar flange standards. Instrument and tubing connections shall conform to SAE J514. Any deviation to either flange connections or tubing connections shall be identified in the proposal with specific details of what the vendor is proposing as an alternative.

● **4.4.5.1** Gray, malleable, ductile, and cast iron flanges shall be flat faced and conform to the dimensional requirements of ISO 7005-2 or ASME B16.1 or ASME B16.42 as specified. PN 20 (Class 125) flanges shall have a minimum thickness equal to PN50 (Class 250) for sizes DN 200 (NPS 8) and smaller.

4.4.5.2 Flat face flanges with full raised face thickness are acceptable on casings (or cylinders) of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ASME are acceptable. Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of nonstandard length, this requirement shall be identified on the arrangement drawing.

4.4.5.3 Machined and studded connections and flanges not in accordance with ISO 7005-1:1992 or, ISO 7005-2:1988 or ASME B16.1, ASME B16.5, ASME B16.42 or ASME B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs and nuts for these nonstandard connections.

NOTE On aeroderivative gas turbines, flanges and tubing according to aircraft industry standards are acceptable.

● **4.4.6** Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1:1992, ISO 7005-2:1988, ASME B16.1, ASME B16.5, ASME B16.42 or ASME B16.47 as specified. Studs and nuts shall be furnished installed, and the first 1.5 threads at both ends of each stud shall be removed.

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

4.5 Rotating Elements

4.5.1 Shafts

4.5.1.1 Shafts shall be designed and manufactured with the capability to transmit the maximum torque that can be developed at any steady state or transient condition in the total operating envelope. The envelope is as defined by the manufacturer within the range of specified site values (see 4.1.19). For generator drives, the vendor shall also specify the transient torque due to short circuit overloads. Also for generator applications the vendor shall specify the power limit, identify the weakest shaft element and, if necessary, provide overload protection.

4.5.1.2 Rotor shaft design shall be one of the following as specified by the vendor:

a) stacked disks or tiebolt(s),

b) welded drum construction, or

c) single-piece construction.

Shafts that have a finished diameter larger than 200 mm (8 in.) shall be forged steel. Shafts that have a finished diameter of 200 mm (8 in.) or less shall be forged steel or, with the purchaser’s approval, hot rolled bar-stock, provided such bar-stock meets all quality and heat treatment criteria established for shaft forgings. Shaft material shall be heat treated steel or high-strength nickel-based alloys.

4.5.1.3 Gas turbine load shaft ends shall conform to API 671. Shafts with splined shaft ends shall conform to ANSI B92.1:1970. Shaft end integral hubs are also acceptable.

4.5.1.4 When shaft radial vibration and/or axial-position probes are furnished, the rotor shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a key-way, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 0.8 µm (32 µin.) R_a, preferably obtained by honing or burnishing.

4.5.1.4.1 The shaft radial vibration sensing areas shall be properly demagnetized to the levels specified in API 670 or otherwise treated so that the combined total electrical and mechanical runout, relative to the journals, does not exceed 15 μm (0.6 mil) peak-to-peak or 25 % of the permissible vibration according to 4.7.5.2.1, whichever is less.

4.5.1.4.2 For areas to be observed by axial-position probes, the shaft mechanical runout shall not exceed 15 μm (0.6 mil).

NOTE 1 See 4.7.5.2.2 and 4.7.5.2.3 for measurement and recording of mechanical and electrical runout.

NOTE 2 If all reasonable efforts fail to achieve the limits noted in 4.5.1.4.1, the vendor and the purchaser shall mutually agree on alternate acceptance criteria.

4.5.2 Rotors

4.5.2.1 Gas generator rotors and rotors of single-shaft gas turbines shall be mechanically designed to safely withstand momentary speeds up to 110 % of the gas turbine trip speed settings throughout the vendor-defined firing temperature range. The vendor shall state in the proposal any inspections that would be required, before restart, after such momentary overspeed conditions have occurred.

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

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

NOTE This requirement may not always be possible to achieve for aeroderivative gas turbines because of their compact design.

4.5.3 Disk and Blading

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

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

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

4.5.3.3 New gas turbine blade designs shall have 8000 documented, continuous, trouble-free operating hours per blade on similar operating conditions as agreed by the purchaser and vendor.

• **4.5.3.4** If specified, the vendor shall present Campbell and Goodman diagrams for the blading backed by demonstrated experience in the application of identical blades operating with the same source or frequency of excitation that is present in the proposed unit. The vendor shall indicate on the Goodman diagrams the standard acceptance margins.

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

4.6 Seals

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

4.6.2 Renewable, by repair or replacement, seals shall be provided at all external points where shafts pass through the casings.

4.7 Dynamics

4.7.1 General

4.7.1.1 This standard recognizes that gas turbine engines are designed and developed as standard products and applied to well-developed gas turbine packaged drive systems. The engine design shall meet the life expectations of 4.1.1. This standard requires that the engine manufacturer conduct the following rotordynamic analysis (see Annex D) and testing as required during the engine development or rotor system modification and submit the data or reports as requested by the purchaser. The following paragraphs, 4.7.1.2 through 4.7.3.6, are a guide to the analytical development and testing report submittals (refer to API 684).

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

a) unbalance in the rotor system;

b) oil-film instabilities (whirl);

c) internal rubs;

d) blade, vane, nozzle, and diffuser passing frequencies;

e) gear-tooth meshing and side bands;

f) coupling misalignment;

g) loose rotor-system components;

h) hysteretic and friction whirl;

i) boundary-layer flow separation;

j) acoustic and aerodynamic cross-coupling forces;

k) asynchronous whirl;

l) ball and race frequencies of rolling element bearings; and

m) electrical line frequency.

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

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

4.7.1.3 Resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range (see 4.1.5) or the specified separation margins (SMs) (see 4.7.2.10 and Figure 1). The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing-support system [see 4.7.2.4 e)].

4.7.1.4 It is recognized aeroderivative gas turbines often exhibit structural resonances in their operating speed range, and yet operate reliably. If significant structural resonances are predicted, the vendor shall demonstrate a history of reliable operation for the subject aeroderivative design. The vendor and purchaser shall mutually agree upon the acceptability of the design for the proposed service.

4.7.1.5 The vendor who is specified to have unit responsibility (see 4.1.2) for the complete drive train shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for its review and included in the instruction manual (see Annex B).

NOTE Examples of undesirable speeds are those caused by the rotor lateral critical speeds, system torsional critical speeds as well as blade and vane resonant modes.

4.7.2 Lateral Analysis

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

NOTE See to Annex D for a lateral analysis flowchart.

4.7.2.2 The location of all critical speeds below the trip speed shall be confirmed on the test stand as required per 6.3.4.3.3. The accuracy of the analytical model shall be demonstrated as required per 4.7.2.15.

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

a) Mode shape plots (relative amplitude vs axial position on the rotor).

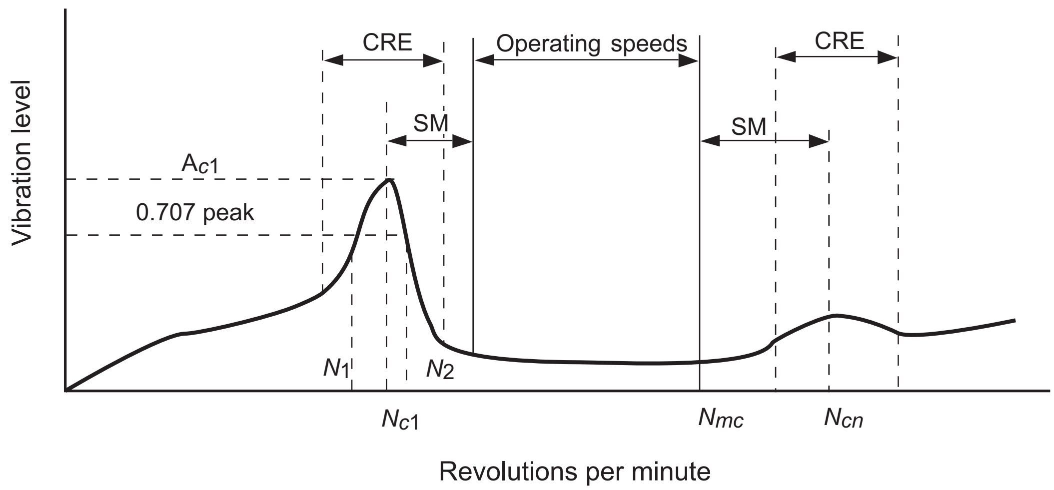
b) Critical speed-support stiffness map (frequency vs support stiffness). Superimposed on this map shall be the calculated system support stiffness, horizontal (k_x) and vertical (k_y) (see Figure 2).

For machinery with widely varying bearing loads and/or load direction such as overhung style machines, the vendor can substitute mode shape plots for the undamped critical speed map and list the undamped critical speed for each of the identified modes.

4.7.2.4 The damped unbalanced response analysis shall include, but shall not be limited to, the following.

NOTE 1 The following is a list of items the analyst is to consider. It does not address the details and product of the analysis which is covered in 4.7.2.7 and 4.7.2.8.

a) Rotor masses and polar and transverse moments of inertia, including coupling halves, and rotor stiffness changes due to shrunk on components.



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

b) Material properties as a function of operating temperature variation along the shaft.

c) Bearing lubricant-film stiffness and damping values including changes due to speed, load, preload, range of oil inlet temperature, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading which may be caused by gear forces (including the changes over the range of maximum to minimum torque), etc.

d) For tilt-pad bearings, the pad pivot stiffness.

e) Structure stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range. For machines whose dynamic structural stiffness values are less than or equal to three and a half times the bearing stiffness values in the range from 0 % to 150 % of N_{mc}, the structure characteristics shall be incorporated as an adequate dynamic system model, calculated frequency dependent structure stiffness and damping values (impedances), or structure stiffness and damping values (impedances) derived from modal or other testing. The vendor shall state the structure characteristics values used in the analysis and the basis for these values (e.g. modal tests of similar rotor structure systems, or calculated structure stiffness values)

f) 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.

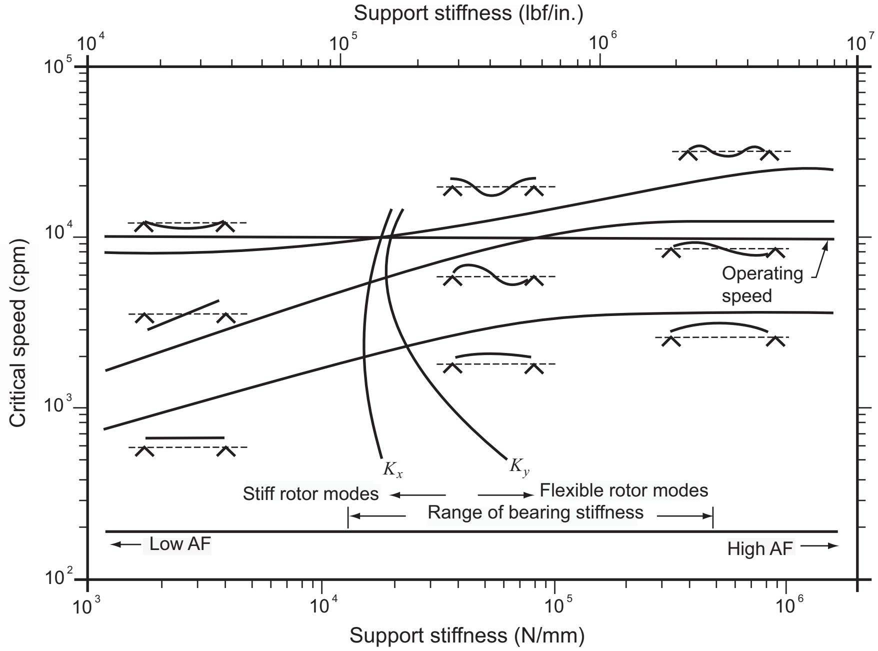


Figure 2—Undamped Critical Speed Map

g) The influence, over the operating range, of the casing shaft end oil seals, if present. Minimum and maximum stiffness will be considered taking into account the tolerance on the component clearance and the oil inlet temperature.

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

i) Squeeze film damper mass, stiffness and damping values considering the component clearance and centering tolerance, oil inlet temperature range, and operating eccentricity.

j) For machines equipped with rolling element bearings, the vendor shall state the bearing stiffness and damping values used for the analysis. The basis for these values or the assumptions made in calculating the values shall be presented.

4.7.2.5 In addition to the damped unbalanced response analysis requirements of 4.7.2.15, for machines equipped with rolling element bearings, the vendor shall state the bearing stiffness and damping values used for the analysis and either the basis for these values or the assumptions made in calculating the values.

• **4.7.2.6** If specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (that is, a train lateral analysis shall be performed).

NOTE In particular, this analysis should be considered for machinery trains with rigid couplings. Refer to API 684 for examples.

4.7.2.7 A separate damped unbalanced response analysis shall be conducted for each critical speed within the speed range of 0 % to 125 % of maximum continuous speed. Unbalance shall analytically be placed at the locations that have been determined by the undamped analysis to affect the particular mode most adversely. For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads and shall be applied at the location of maximum displacement. For conical (asymmetric) modes, an unbalance shall be added at the location of maximum displacement nearest to each journal bearing. These unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing. Figure 3 shows the typical mode shapes and indicates the location and definition of U for each of the shapes. The magnitude of the unbalances shall be two times the value of U as calculated by Equation (2a) and Equation (2b).

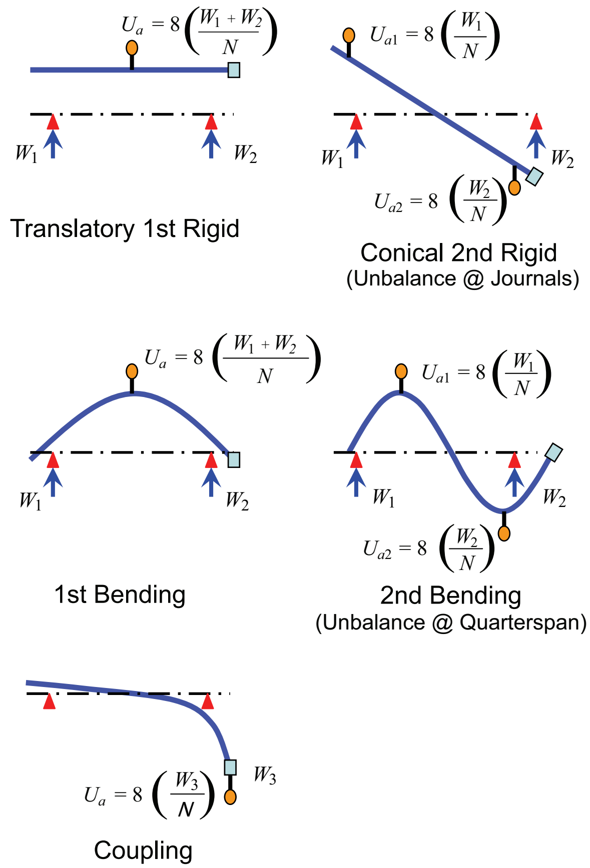


Figure 3—Between Bearing Machines

In SI units:

$$U = 6350\ W/N \tag{2a}$$

or 0.254 μm mass displacement, whichever is greater.

In USC units:

$$U = 4\ W/N \tag{2b}$$

or 10 μin. mass displacement, whichever is greater.

where

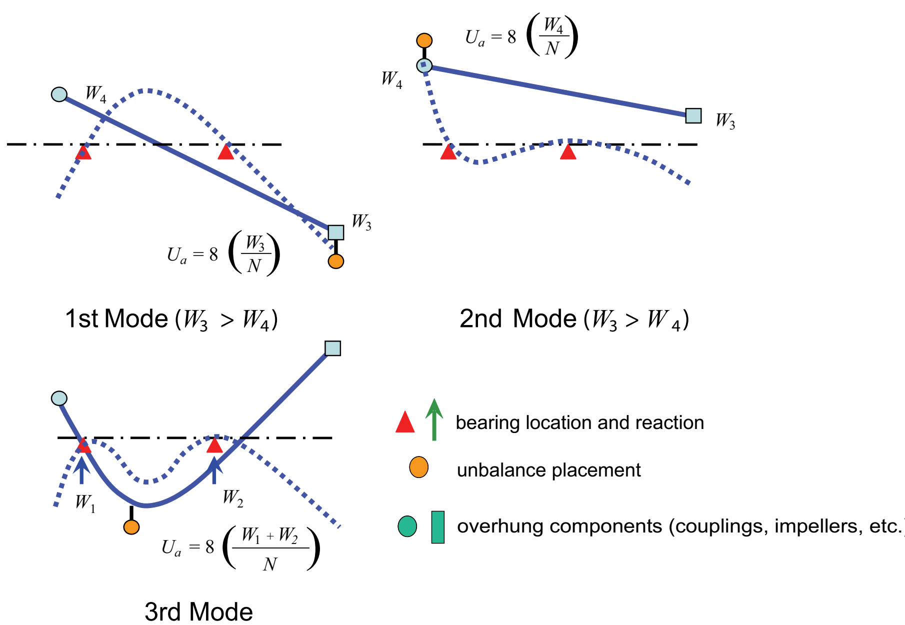
U is the input unbalance for the rotordynamic response analysis in g-mm (oz-in.);

N is the maximum continuous operating speed, in revolutions per minute;

W is the journal static load in kg (lbm), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (that is the mass of the rotor outboard of the bearing) in kg (lbm) (see Figure 3).

NOTE The limits on mass displacement are in general agreement with the capabilities of conventional balance machines, and are necessary to invoke for small rotors running at speeds running above 25,000 revolutions per minute.

4.7.2.7.1 For rotors where the impellers disc(s) are cantilevered beyond the journal bearings, unbalance shall be added at the impellers disc(s) and components such as locknuts, shaft end seals and the coupling for the case of the nonintegrally geared rotors. Each mode that is less than 150 % of maximum continuous speed shall be analyzed. The modes shall be calculated at minimum and maximum support stiffness and in the case of integrally geared rotors include the change in support stiffness resulting from minimum to maximum torque transmitted through the gearing. The unbalance shall be located at or close to the component center of gravity and phased to create maximum synchronous response amplitude. Figure 4 shows the typical mode shapes and indicates the location and definition of U for each of the shapes.



NOTE Rigid (solid) and flexible (dashed) shaft modes shown.

Figure 4—Overhung Machines

4.7.2.7.2 For rotors which are between bearing designs, unbalance shall be added at the impellers disc(s) and major rotor components. The unbalance shall be located at or close to the component center of gravity and phased to create maximum synchronous response amplitude.

4.7.2.8 As a minimum, the damped unbalanced response analysis shall produce the following.

NOTE The following is the list of analysis details and identifies the deliverables. The items to be considered in the analysis were identified in 4.7.2.4.

a) Identification of the frequency of each critical speed, regardless of the AF, in the range from 0 % to 150 % of the maximum continuous speed.

b) Frequency, phase, and response amplitude data (Bode plots) at the vibration probe locations through the range of each critical speed resulting from the unbalance specified in 4.7.2.7.

c) The plot of deflected rotor shape for each critical speed resulting from the unbalances specified in 4.7.2.7, showing the major-axis amplitude at each coupling plane of flexure, the centerlines of each bearing, the locations of each radial probe, and at each seal throughout the machine as appropriate. The minimum design diametral running clearance of the seals shall also be indicated.

d) Additional Bode plots that compare absolute shaft motion with shaft motion relative to the bearing housing for machines where the support stiffness is less than three and a half times the oil-film stiffness.

4.7.2.9 Additional analyses shall be made for use with the verification test specified in 4.7.2.15. The location of the unbalance shall be determined by the vendor. Any test stand parameters which influence the results of the analysis shall be included.

NOTE For some machines, there will only be one plane readily accessible for the placement of an unbalance; e.g. the coupling flange on a single ended drive machine. However, there is the possibility that multiple planes are available on axial compressors. In this situation, it is possible to excite other critical speeds. Multiple analyses may be required to avoid any detrimental effect of the unbalanced operation.

4.7.2.10 The damped unbalanced response analysis shall indicate that the machine will meet the following SM (see Figure 1):

a) if the AF at a particular critical speed is less than 2.5, the response is considered critically damped and no SM is required;

b) if the AF at a particular critical speed is equal to 2.5 or greater and that critical speed is below the minimum speed, the SM (as a percentage of the minimum speed) shall not be less than the value from Equation (3) or the value of 16, whichever is less;

$$SM = 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{3}$$

c) if the AF at a particular critical speed is equal to 2.5 or greater and that critical speed is above the maximum continuous speed, the SM (as a percentage of the maximum continuous speed) shall not be less than the value from Equation (4) or the value of 26, whichever is less.

$$SM = 10 + 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{4}$$

4.7.2.11 The calculated unbalanced peak-to-peak amplitudes [see 4.7.2.8 b)] shall be multiplied using the correction factor calculated from Equation (5) for each unbalance case considered. The correction factor shall have a value greater than 1.0.

$$CF = \frac{A_1}{A_{2x}} \tag{5}$$

where

CF is the correction factor;

A_1 is the amplitude limit, calculated using Equation (6a) or Equation (6b) in μm (mils) peak-to-peak;

A_{2X} is the maximum peak-to-peak amplitude at the probe location per requirements of 4.7.2.8 b) in μm (mils) peak-to-peak through maximum continuous speed.

In SI units:

$$A_1 = 25.4\sqrt{\frac{12,000}{N}} \tag{6a}$$

In USC units:

$$A_1 = \sqrt{\frac{12,000}{N}} \tag{6b}$$

where

N is the maximum continuous operating speed, in revolutions per minute.

4.7.2.12 The calculated major-axis, peak-to-peak, unbalanced rotor response amplitudes, corrected in accordance with 4.7.2.11 at any speed from zero to trip speed shall not exceed 75 % of the minimum design diametral running clearances throughout the machine (with the exception of floating-ring seal locations). For machines with abradable seals, the response amplitude to the running clearance shall be mutually agreed.

NOTE Running clearances may be different than the assembled clearances with the machine shutdown.

4.7.2.13 If the analyses indicate that the criteria regarding the AF and SM in 4.7.2.10 or the criteria regarding unbalance rotor response amplitudes in 4.7.2.11 and 4.7.2.12 cannot be met, the vendor is permitted to demonstrate a history of reliable operation of comparable machines, or to perform an unbalance sensitivity test to demonstrate that the machine still may be acceptable. The vendor and purchaser shall agree upon the acceptability of the design for the proposed service.

The unbalance weight(s) shall be applied to most adversely excite the response peak(s) in question. The magnitude of the weight(s), defined in Figure 3 or Figure 4, and the resulting measured vectorial change shall not exceed the vibration acceptance limits defined in Equations 6a and 6b, and the clearance check of 4.7.2.12. In case it is not possible to place the unbalance weight(s) in accordance with the mode shape of the particular resonance (see 4.7.2.7.1), scaling must be performed to verify that the requirements are fulfilled. The magnitude of the unbalance weight(s) shall be scaled for the mode(s) in question by the ratio between 1) the maximum modal amplitude, and 2) the modal amplitude at the balance plane where the weight is applied.

4.7.2.14 If specified, in addition to the other requirements of 4.7.2, the lateral analysis report shall include the following:

a) dimensional data of the bearing design in sufficient detail to enable calculations of stiffness and damping coefficients;

b) the weight, polar and transverse moments of inertia and center of gravity of the impellers/disk(s), blades, balance piston, shaft end seals and coupling(s) with sufficient detail to conduct an independent analysis of the rotor;

c) the mass elastic model used for the vendors' analysis;

d) the support stiffness used in the analysis and its basis.

4.7.2.15 Unbalanced Rotor Response Verification Test—This section is applicable only for a gas turbine with a modified bearing or rotor configuration or a gas turbine prototype.

4.7.2.15.1 An unbalanced rotor response test shall be performed as part of the mechanical running test and the results shall be used to verify the analytical model. The actual response of the rotor on the test stand to the same arrangement of unbalance and bearing loads as was used in the analysis specified in 4.7.2.9 shall be the criterion for determining the validity of the damped unbalanced response analysis. To accomplish this, the requirements of 4.7.2.15.1 through 4.7.2.15.4 shall be followed.

a) During the mechanical running test, the one times operating speed amplitude and phase angle of the shaft vibration, from zero to trip speed shall be recorded.

   NOTE This set of readings is normally taken during a coast down, with convenient increments of speed such as 50 revolutions per minute.

b) The location of critical speeds below the trip speed shall be established.

c) The unbalance which was used in the analysis performed in 4.7.2.9, multiplied by the appropriate correction factor, shall be added to the rotor in the location used in the analysis. The unbalance shall not exceed eight times the value from Equation (2).

d) The machine shall then be brought up to the trip speed and the indicated vibration amplitudes and phase shall be recorded using the same procedure used for 4.7.2.15.1 a).

e) The corresponding indicated vibration data taken in accordance with 4.7.2.15.1 a) shall be vectorially subtracted from the results of this test.

NOTE It is practical to store the residual unbalance (see Annex C) vibration measurements recorded in the step at 4.7.2.15.1 a) and by use of computer code perform the vectorial subtraction called for in this paragraph at each appropriate speed. This makes the comparison of the test results with the computer analysis of 4.7.2.9 quite practical. It is necessary for probe orientation be the same for the analysis and the machine for the vectorial subtraction to be valid.

f) The results of the mechanical running test, including the unbalance response verification test, shall be compared with those from the analytical model specified at 4.7.2.9.

4.7.2.15.2 The vendor shall correct the model if it fails to meet either of the following criteria.

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

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

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

4.7.2.15.3 If the support stiffness is less than two times the bearing oil film stiffness, the absolute vibration of the bearing housing shall be measured and vectorially added to the relative shaft vibration, in both the balanced [see 4.7.2.15.1 a)] and in the unbalanced [see 4.7.2.15.1 c)] condition before proceeding with the step specified in 4.7.2.15.1 f). In such a case, the measured response shall be compared with the predicted absolute shaft movement.

4.7.2.15.4 After correcting the model, the requirements of 4.7.2.11 shall be confirmed.

4.7.2.15.5 The major axis vibration amplitudes shall be evaluated from each pair of vibration probes at each vibration response peak after correcting the model, if required, to determine the maximum amplitude of vibration. The major-axis amplitudes of each response peak shall not exceed the limits specified in 4.7.2.12.

4.7.2.16 Stability Analysis:

4.7.2.16.1 A stability analysis shall be performed on all gas turbines that meet the following:

a) those rotors whose maximum continuous speed is greater than the first undamped critical speed on rigid supports in accordance with 4.7.2.3;

b) those rotors with fixed geometry bearings.

The stability analysis shall be calculated at the maximum continuous speed. The machine inlet and discharge conditions shall be at either the rated condition or another operating point unless the vendor and purchaser agree upon another operating point.

NOTE The Level I stability analysis (refer to API 684) was developed to fulfill two purposes. First, it provides an initial screening to identify rotors that do not require a more detailed study. The approach as developed is conservative. Second, the Level I analysis specifies a standardized procedure that is applied to all manufacturers similar to the lateral analysis found in 4.7.2. (Refer to API 684 for a detailed explanation of a Level 1 stability analysis.)

4.7.2.16.2 The model used in the Level I stability analysis shall include the items listed in 4.7.2.4 together with the effects of squeeze film dampers where used.

4.7.2.16.3 All bearings shall be analyzed using the extreme values of oil inlet temperature and operating limits for clearance to produce the minimum log decrement.

4.7.2.16.4 When tilt pad journal bearings are used, the analysis shall be performed with synchronous tilt pad coefficients.

4.7.2.16.5 The anticipated cross-coupling, Q_A, present in the rotor is defined by the following procedures.

a) For centrifugal flow rotors:

the parameters in Equation (7) shall be determined based on the specified operating condition in 4.7.5.1.

$$q_a = \frac{(HP)B_cC}{D_cH_cN_r}\left(\frac{\rho_d}{\rho_s}\right) \tag{7}$$

Equation (7) is calculated for each impeller of the rotor. Q_A is equal to the sum of q_A for all impellers.

NOTE For axial flow rotors:

$$q_a = \frac{(HP)B_tC}{D_tH_tN_r} \tag{8}$$

Equation (8) is calculated for each stage of the rotor. Q_A is equal to the sum of q_a for all stages.

Symbols:

B_c	impeller efficiency change per displacement, 3;
B_t	stage efficiency per displacement, 1.5;
C	units conversion constant, 9.55 (63);
D_c	impeller diameter, mm (in.);
D_t	blade pitch diameter, mm (in.);
H_c	minimum of diffuser or impeller discharge width per impeller, mm (in.);
H_t	effective blade height, mm (in.);
HP	rated power per stage or impeller, W (hp);
N_r	normal operating speed for calculation of aerodynamic excitation (revolutions per minute);
q_a	anticipated cross-coupling for the rotor, kN/mm (klbf/in.);
ρ_d	discharge gas density per stage or impeller, kg/m^3 (lbm/ft^3);
ρ_s	suction gas density per stage or impeller, kg/m^3 (lbm/ft^3).

defined as:

$$Q_A = \sum_{i=1}^{S} q_{ai}$$

where

q_a is the cross-coupling defined in Equation (7) or Equation (8) for each stage or impeller, kN/mm (klbf/in.);

S is the number of stages or impellers;

δ is the logarithmic decrement;

= $2\Pi\xi(1-\xi^2)^{0.5}$

where

ξ is the damping ratio;

δ_A is the minimum log decrement at the anticipated cross-coupling for either minimum or maximum bearing clearance;

δ_b is the basic log decrement of the rotor and support system only.

4.7.2.16.6 An analysis shall be performed with a varying amount of cross-coupling introduced at the rotor mid-span for between bearing rotors or at the center of gravity of the stage or impeller disk(s) for single overhung rotors. For double overhung rotors, the cross-coupling shall be placed at each stage or impeller concurrently and should reflect the ratio of the anticipated cross-coupling, (q_a, calculated for each impeller or stage).

4.7.2.16.7 The applied cross-coupling shall extend from zero to the minimum of the following:

a) a level equal to 10 times the anticipated cross-coupling, Q_A;

b) the amount of the applied cross-coupling required to produce a zero log decrement, Q_0. This value can be reached by extrapolation or linear interpolation between two adjacent points on the curve. Q_0 is the minimum cross-coupling needed to achieve a log decrement equal to zero for either minimum or maximum bearing clearance, kN/mm (klbf/in.).

4.7.2.16.8 A plot of the calculated log decrement, for the first forward mode shall be prepared for the minimum and maximum bearing clearances. Each curve shall contain a minimum of five calculated stability points. The ordinate (y-axis) shall be the log decrement. The abscissa (x-axis) shall be the applied cross-coupling with the range defined in 4.7.2.16.6. For double overhung rotors, the applied cross-coupling will be the sum of the cross-coupling applied to each impeller or stage.

A typical plot is presented in API 684. Q_0 and Q_A are identified as the minimum values from either bearing clearance curves.

Acceptable stability exists if both of the following criteria are met, specifically:

a) $Q_0/Q_A > 2.0$,

b) $\delta_A > 0.1$.

4.7.2.16.9 If after all practical design efforts have been exhausted to achieve the requirements of 4.7.2.16.8, acceptable levels of the log decrement, δ_A , shall be mutually agreed upon by the purchaser and vendor

4.7.3 Torsional Analysis

• **4.7.3.1** For gas turbine-driven units, the vendor having unit responsibility shall ensure that a torsional vibration analysis of the complete coupled train is carried out and shall be responsible for directing any modifications necessary to meet the requirements of 4.7.3.1 through 4.7.3.6. If specified, the data for a third party torsional analysis shall be provided.

NOTE See Annex D for a torsional analysis flowchart.

4.7.3.2 Excitation of torsional natural frequencies may come from many sources which may or may not be a function of running speed and should be considered in the analysis. These sources shall include but are not limited to the following:

a) gear characteristics such as unbalance, pitch line runout, and cumulative pitch error;

b) cyclic process impulses;

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

d) torsional excitation resulting from electric (starter/helper) motors;

e) control loop resonance from hydraulic, electronic governors, and variable frequency drives (VFDs);

f) one and two times line frequency;

g) running speed or speeds;

h) harmonic frequencies from VFDs.

4.7.3.3 The torsional natural frequencies of the complete train shall be at least 10 % above or 10 % below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed, see 4.1.5).

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

4.7.3.5 When torsional resonances are calculated to fall within the margin specified in 4.7.3.3 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

4.7.3.6 In addition to the torsional analyses required in 4.7.3.2 through 4.7.3.5, the vendor shall perform a transient torsional vibration analysis for turbine driven trains containing generators or helper/start motors, using a time-transient analysis. The requirements of 4.7.3.6.1 through 4.7.3.6.3 shall be followed.

4.7.3.6.1 In addition to the parameters used to perform the torsional analysis specified in 4.7.3.1, the following shall. be included:

a) motor average torque, as well as pulsating torque (e.g. 6× and 12× for VFD) vs speed (or time) characteristics;

b) generator average torque, as well as pulsating torque (direct and quadrature axis) vs speed (or time) characteristics.

4.7.3.6.2 The analysis shall generate the maximum torque as well as a torque vs time history for each of the shafts in the machinery train. The maximum torques shall be used to evaluate the peak torque capability of coupling components, gearing and interference fits of components such as coupling hubs. The torque vs time history shall be used to develop a cumulative damage fatigue analysis of shafting, keys and coupling components. Appropriate fatigue properties and stress concentrations shall be used.

4.7.3.6.3 An appropriate cumulative fatigue algorithm shall be used to develop a value for the safe number of starts/ short circuits. The safe number of starts/short circuits shall be as mutually agreed by the purchaser and vendor.

NOTE 1 Values used depend on the analytical model used and the vendor's experience. Values of 1000 to 1500 starts are common. API 541 requires 5000 starts. This is a reasonable assumption for a motor since it does not add significant cost to the design. The driven equipment, however, would be designed with overkill to meet this requirement.

EXAMPLE 20-year life, 1 start/week = 1040 starts. Equipment of this type normally would start once every few years rather than once per week. A reasonable number of starts should therefore be agreed upon.

NOTE 2 The number of short circuit events can be substantially lower.

4.7.4 Balancing

4.7.4.1 Introduction (Refer to ISO 19499)

Rotors shall be balanced in accordance with the following procedures:

a) Rotors with rigid behavior shall be balanced at low speed in two planes per ISO 1940-1. If the first flexural critical speed exceeds the maximum operating speed by at least 50 %, then the rotor can normally be considered rigid for balancing purposes.

b) Rotors with flexible behavior require multiplane balancing at high speed or low speed balancing in stages during assembly (see ISO 11342). Rotors that do not satisfy the rigid rotor definition can be considered flexible for balancing purposes.

c) When a rotor with a keyway is balanced, the keyway shall be filled with a fully crowned half key, in accordance with ISO 8821.

d) The vendor shall submit the balancing procedure for information.

e) Balancing results shall be reported indicating which balancing method has been used, balancing weights or other corrections made (magnitude and location), residual unbalance and permissible residual unbalance.

4.7.4.2 Low-speed Balancing

4.7.4.2.1 With the use of appropriate procedures, it is often possible to balance flexible rotors at low speed so as to ensure satisfactory running when the rotor is installed in its final environment.

4.7.4.2.2 Major parts of the rotating element, such as the shaft, balancing drum, impellers or disks, shall be individually dynamically balanced before assembly, to ISO 1940-1, Quality Grade G 0.67 (see Figure 5).

4.7.4.2.3 The assembled rotating element shall be multiplane dynamically balanced per ISO 1940-1, Quality Grade 0.67 (equivalent to $4W/N$).

NOTE See API 687:2001, Chapter 3, Section 4.4, for special considerations for balancing tie bolt rotors.

4.7.4.2.4 The maximum allowable residual unbalance (see Annex C), U_r, per plane (journal) shall be calculated as follows.

In SI units:

$$U_r = 6350\ W/N \text{ for } N < 25{,}000 \text{ revolutions per minute} \tag{9a-1}$$

$$U_r = W/3.937 \text{ for } N \geq 25{,}000 \text{ revolutions per minute} \tag{9a-2}$$

In USC units:

$$U_r = 4\ W/N \text{ for } N < 25{,}000 \text{ revolutions per minute} \tag{9b-1}$$

$$U_r = W/6250 \text{ for } N \geq 25{,}000 \text{ revolutions per minute} \tag{9b-2}$$

where

U_r is the maximum allowable residual unbalance, g-mm (oz-in.);

N is the maximum continuous operating speed, revolutions per minute;

W is the journal static load, kg (lbm).

NOTE The residual unbalance requirement of this paragraph implies engine life is somehow increased by balancing the rotor to this level. This, in fact, might not be the case. Engine is life limited by highly stressed parts or components operating at very high temperatures. The vendor can request purchaser's approval to balance to the vendor's standard, provided that the vendor can show, by successful proven operating experience, engine life is not compromised. Typically, the unbalance should not exceed $15W/N$ or ISO 1940, Grade 2.5.

4.7.4.3 High-speed Balancing

● **4.7.4.3.1** If specified, high-speed balancing shall be performed according to procedures described in ISO 11342.

● **4.7.4.3.2** If high-speed balancing has been specified, the acceptance criteria shall be according to Item a), Item b), or Item c), as specified:

a) residual unbalance criteria according to Quality Grade G 2.5;

b) pedestal vibration derived according to the methods described in ISO 11342, Section 8.2.5;

c) pedestal vibration of 1.0 mm/s.

4.7.4.3.3 The vendor shall provide, in the proposal, the balancing procedure and the acceptance criteria for the balancing procedure required by 4.7.4.3.1.

● **4.7.4.3.4** If specified, for a rotor that has been low-speed sequentially balanced (see 4.7.4.2), and when specified for rotors that are high-speed balanced (see 4.7.4.3), a low-speed residual unbalance check shall be performed in a low-speed balance machine or in a high-speed balance machine capable of low-speed balance. The unbalance magnitude and phase relative to each journal shall be recorded.

NOTE This check is done to provide a reference of residual unbalance and phase for future use in a low-speed balance machine.

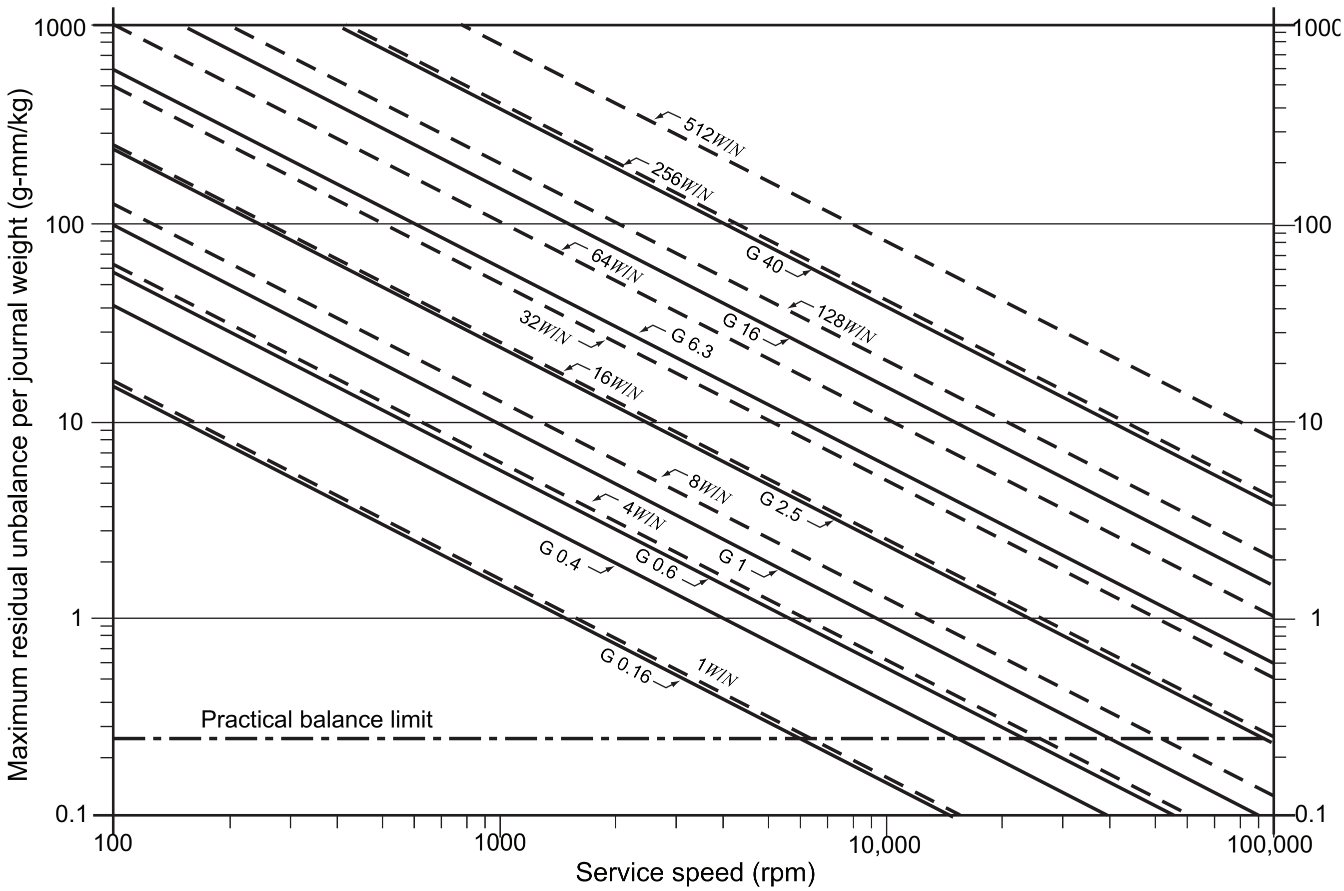


Figure 5—API and ISO Balance Grades

4.7.5 Vibration

4.7.5.1 Introduction

Machine vibrations can be measured on rotating shafts and/or on nonrotating parts measured on either or both the rotating shafts and casings. ISO 7919-1 and ISO 7919-4 give guidelines for applying evaluation criteria for shaft vibration under normal conditions, measured at or close to the bearings of gas turbine sets. ISO 10816-1 and ISO 10816-4 give specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of industrial gas turbine-driven sets. See Table 4 for the limits.

4.7.5.1.1 The evaluation criteria in the ISO 10816 and ISO 7919 are based on the following evaluation zones.

a) Zone A—The vibration of newly commissioned machines would normally fall within this zone.

b) Zone B—Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

c) Zone C—Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

d) Zone D—Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

4.7.5.1.2 The vibration criteria provided in ISO 7919-4 and ISO 10816-4 apply to industrial gas turbine sets used in electrical and mechanical drive applications per API 616 covering the power range above 1 MW and a speed range under load between 3000 revolutions per minute and 25,000 revolutions per minute. Aeroderivative gas turbines (including gas turbines with dynamic properties similar to those of aeroderivatives but not free power turbines) are excluded from this vibration criteria.

NOTE The 1 MW power limit for API 616 is less than the 3 MW specified in ISO 7919-4 and ISO 10816-4.

Table 4—Vibration Limits According to ISO 10816-4 and ISO 7919-4

Zone	Bearing Housing Pedestal Criteria Vibration Limits per ISO 10816-4 mm/s (RMS)	Shaft Relative Vibration Limits per ISO 7919-4 $A_{(\rho-\rho)}$ µm
A	≤4.5	≤4800/ $\sqrt{N}$
B	4.5 to 9.3	4800/ $\sqrt{N}$ to 9000/ $\sqrt{N}$
C	9.3 to14.7	9000/ $\sqrt{N}$ to 13,200/ $\sqrt{N}$
D	≥14.7	≥13,200/ $\sqrt{N}$

4.7.5.1.3 The bearing housing/pedestal vibration limits in Table 4 apply to radial vibration measurements and to axial vibration measurements on housings containing an axial thrust bearing, under steady state operating conditions at rated speed.

4.7.5.2 Vibration Measured During Factory Test

4.7.5.2.1 Acceptance Criteria

Acceptance criteria, during the mechanical running test, are based on shaft vibration or on bearing housing vibration as specified by the vendor. During steady state operation, operating at its maximum continuous speed or at any other speed within the specified operating speed range (see 4.1.5), the vibration shall not exceed the following values.

a) Shaft relative vibration [$A_{(\rho-\rho)}$] for Zone A in ISO 7919-4 is as follows.

In SI units:

$$A_{(\rho-\rho)} = 4800/\sqrt{N}\ \mu\text{m} \tag{10a}$$

In USC units:

$$A_{(\rho-\rho)} = 190/\sqrt{N}\ \text{mils} \tag{10b}$$

where

$A_{(\rho-\rho)}$ is the magnitude of unfiltered vibration, µm (mils) peak-to-peak;

N is the maximum continuous operating speed, in revolutions per minute.

b) Bearing housing or casing vibration for Zone A in ISO 10816-4 is 4.5 mm/s (0.18 in./s) RMS, broadband.

The RMS measurement is broadband vibration over a frequency range from 10 Hz to at least 500 Hz or six times the maximum normal operating speed, whichever is greater.

4.7.5.2.2 At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration magnitude shall not increase more than 12.7 μm (0.5 mil) for shaft relative vibration or 1.5 mm/s (0.06 in./s) for bearing housing or casing vibration above the maximum value recorded at the maximum continuous speed. Any nonsynchronous discrete vibration shall not exceed 20 % of the synchronous vibration magnitude.

NOTE These limits are not to be confused with the limits specified in 4.7.2.15 for shop verification of unbalanced response.

4.7.5.2.3 Electrical and mechanical runout shall be determined by rotating the rotor through the full 360° supported in V-blocks at the journal centers while continuously recording the combined runout with a noncontacting vibration probe and measuring the mechanical runout with a dial indicator at the centerline of each probe location and one probe-tip diameter to either side.

NOTE The rotor runout determined above generally may not be reproduced when the rotor is installed in a machine with hydrodynamic bearings. This is due to pad orientation on tilt pad bearings and effect of lubrication in all journal bearings. The rotor will assume a unique position in the bearings based on the slow roll speed and rotor weight.

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

4.7.5.2.5 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 % of the allowable vibration calculated from Equation (10) or 15 μm (0.6 mil), whichever is less, can be vectorially subtracted from the vibration signal measured during the factory test.

4.7.5.3 Vibration Measured in the Field (in Situ)

4.7.5.3.1 Acceptance Limits During Commissioning

Acceptance criteria are based on shaft vibration or on bearing housing vibration as specified by the vendor. The limits shall apply to vibration measurements under steady-state operating conditions at rated speeds.

a) Shaft relative vibration.

In SI units:

$$A_{(\rho-\rho)} = 7000/\sqrt{N} \text{ μm} \tag{11a}$$

In USC units:

$$A_{(\rho-\rho)} = 275/\sqrt{N} \text{ mils} \tag{11b}$$

where

$A_{(\rho-\rho)}$ is the magnitude of unfiltered vibration, μm peak-to-peak;

N is the maximum continuous speed in revolutions per minute.

or

b) Bearing housing or casing vibration: 6.5 mm/s (0.25 in./s) RMS, broadband.

The RMS measurement is broadband vibration over a frequency range from 10 Hz to at least 500 Hz or six times the maximum normal operating speed, whichever is greater.

4.8 Bearings and Bearing Housing

4.8.1 General

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

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

4.8.2 Rolling Element Bearing

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

a) rotor weight reactions,

b) vibratory loading,

c) preloading,

d) misalignment,

e) gear loads,

f) combined thrust and radial loads,

g) off-design point loads,

h) blade-out loads (loss of a blade),

i) surge loading.

4.8.2.2 Bearing load rating and calculation methods shall meet or exceed the requirements of ABMA Std 9 for ball bearings and ABMA Std 11 for roller bearings.

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

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

4.8.2.5 Bearings shall be selected to meet an L10 rated life of 50,000 hours continuous operation at ISO continuous rating conditions and 32,000 hours at maximum axial and radial loads and rated speed. The basic rating L10 life shall be calculated in accordance with ISO 281:2007.

4.8.3 Hydrodynamic Radial Bearings

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

4.8.3.2 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances to limit rotor vibration to the maximum specified amplitudes (see 4.7.2.16) while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency.

4.8.3.3 The liners, pads, or shells shall be in axially split bearing housings and shall be replaceable with minimal dismantling of any portion of the casing.

4.8.3.4 Bearings shall be designed to prevent incorrect positioning.

4.8.4 Thrust Bearings

4.8.4.1 General

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

4.8.4.1.2 Thrust bearings shall be sized for continuous operation through the full operating range including the most adverse specified operating conditions. Calculation of the thrust load shall include but shall not be limited to the following factors:

a) fouling and variation in seal clearances at design and at twice the design internal clearance;

b) step thrust from all diameter changes;

c) stage reaction and stage differential pressure;

d) variations in inlet, bleed, injection, and exhaust conditions;

e) external loads from the driven equipment, as described in 4.8.4.1.3 through 4.8.4.1.5.

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

In SI units:

$$F = [(0.25) \times (9550) \times P_r]/(N_r \times D) \tag{12a}$$

In USC units, this translates to:

$$F = [(0.25) \times (63{,}000) \times P_r]/(N_r \times D) \tag{12b}$$

where

F is the external thrust force, in kN (lb);

0.25 is the applied coefficient friction of gear teeth friction;

P_r is the rated power, in kW (hp);

N_r is the rated speed, in revolutions per minute;

D is the shaft diameter at the coupling in mm (in.).

NOTE Shaft diameter is used to approximate gear coupling pitch diameter.

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

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

4.8.4.2 Hydrodynamic Thrust Bearings

Hydrodynamic thrust bearings shall be in accordance with 4.8.4.2.1 through 4.8.4.2.5.

4.8.4.2.1 Hydrodynamic thrust bearings shall be of the steel-backed babbitted multisegment type, designed for the maximum thrust on the active side. The bearing shall be arranged for continuous pressurized lubrication and shall be of the tilting-pad type, incorporating a self-leveling feature that ensures that each pad carries an equal share of the thrust load with minor variation in pad thickness.

It is preferred that both the active and inactive sides of the thrust bearing use the same size and type of tilt-pad bearing; however, it is recognized that other bearing types may be used on the inactive side.

4.8.4.2.2 Each pad shall be designed and manufactured with dimensional precision (thickness variation) that will allow the interchange or replacement of individual pads.

4.8.4.2.3 Integral thrust collars are preferred for hydrodynamic thrust bearings. If integral collars are furnished, they shall be provided with at least 3.0 mm ($^1/_8$ in.) of additional stock to enable refinishing if the collar is damaged. If replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

4.8.4.2.4 Both faces of the thrust collars for hydrodynamic thrust bearings shall have a surface finish of 0.4 μm (16 μin.) R_a or better and after mounting, the axial total indicated run out of either face shall not exceed 13 μm (0.0005 in.).

4.8.4.2.5 Hydrodynamic thrust bearings shall be selected such that under any operating condition the load does not exceed 50 % of the bearing manufacturer's ultimate load rating at site rated power. The ultimate load rating is the load that will produce the minimum acceptable oil-film thickness without inducing failure during continuous service or the load that will not exceed the creep-initiation or yield strength of the babbitt at the location of maximum temperature on the pad, whichever load is less. In sizing thrust bearings, consideration shall be given to the following for each specific application:

a) the shaft speed;

b) the temperature of the bearing babbitt;

c) the deflection of the bearing pad;

d) the minimum oil-film thickness;

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

f) the design configuration of the bearing;

g) the babbitt alloy;

h) the turbulence of the oil film.

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

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

4.8.5 Bearing Housings

4.8.5.1 Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 33 °C (60 °F) under the most adverse specified operating conditions (see 4.1.19). If the vendor's design inlet oil temperature exceeds 50 °C (122 °F), special consideration shall be given to bearing design, oil flow and viscosity, and allowable temperature rise.

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

4.8.5.3 Where space allows, provision shall be made for mounting two radial-vibration probes in each bearing housing, two axial-position probes at the thrust end of each machine, and one-event-per-revolution probe in each machine. The probe installation shall be as specified in API 670.

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

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

4.9 Lubrication

4.9.1 Unless otherwise specified, bearings and bearing housings shall be arranged for oil lubrication using a mineral oil in accordance with ISO 8068:2006.

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

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

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

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

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

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

b) any continuously lubricated couplings;

c) any governing and control-oil system;

d) the seal-oil system, if combined with the lube-oil system.

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

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

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

a) reservoir retention time,

b) synthetic oil supply temperature,

c) reservoir material,

d) drain system slopes,

e) twin oil coolers,

f) instrumentation items.

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

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

4.10 Materials

4.10.1 General

Except as required or prohibited by this standard or by the purchaser, materials of construction shall be selected by the manufacturer for the operating and site environmental conditions specified (see 4.1.19, 5.6.1.8, and 5.6.1.9).

4.10.1.1 Materials of construction shall be manufacturer's standard for the specified operating conditions, except as required or prohibited by datasheets or this standard (see 5.5.1 for requirements for auxiliary piping materials). The purchaser will specify (see 5.6.1.9) any corrosive agents present in the motive and process fluids, and/or in the environment. The materials of construction of all major components and all other components which come in contact with the purchaser's specified corrosive agents shall be clearly stated in the vendor's proposal. Any changes to the vendor's standard parts lives service life which are due to the purchaser's specified corrosive agents shall also be clearly stated in the vendor's proposal.

4.10.1.2 The materials of construction of all major components shall be clearly stated in the vendor's proposal. Materials shall be identified by reference to applicable international standards, including the material grade. When no such designation is available, the vendor's material specification, giving material properties, chemical composition, and test requirements, shall be included in the proposal. Any component or coating material which does not have at least 16,000 hours total experience (of which 8000 hours shall be continuous in one machine) shall be identified in the proposal.

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

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

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

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

4.10.1.6 The purchaser shall specify any corrosive agents (including trace quantities) present in the motive and process fluids and in the site environment, including constituents that may cause stress corrosion cracking or attack elastomers.

NOTE Typical agents of concern are hydrogen sulfide, amines, chlorides, bromides, iodides, cyanides, fluorides, naphthenic acid and polythionic acid. Other agents affecting elastomeric selection include ketones, ethylene oxide, sodium hydroxide, methanol, benzene, and solvents.

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

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

4.10.1.8 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and compatible with the specified gas.

● **4.10.1.9** If the purchaser has specified the presence of hydrogen sulfide in any fluid, materials exposed to that fluid shall be selected in accordance with the requirements of NACE MR 0175.

4.10.1.10 The vendor shall select materials to avoid conditions that may result in electrolytic corrosion. Where such conditions cannot be avoided, the purchaser and the vendor shall agree on the material selection and any other precautions necessary.

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. The NACE *Corrosion Engineer's Reference Book* is one resource for selection of suitable materials in these situations.

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

4.10.1.12 Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice are acceptable. The use of steel made to a course austenitic grain size practice (such as ASTM A515) is prohibited. The use of ASTM A515 steel is prohibited. Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or low temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice are acceptable.

4.10.1.13 The minimum quality bolting material for pressure joints shall be carbon steel (such as ASTM A307, Grade B) for cast iron casings and high-temperature alloy steel (such as ASTM A193, Grade B7) for steel casings. Carbon steel nuts (such as ASTM A194, Grade 2H) shall be used, where space is limited, case hardened carbon steel nuts (such as ASTM A563 Grade A) shall be used. For temperatures below –30 °C (–20 °F), low-temperature bolting material (such as ASTM A320) shall be used.

4.10.1.14 Positive material identification (PMI) test methods are intended to identify alloy materials and are not intended to establish the exact conformance of a material to an alloy specification. PMI is used to verify that the specified materials are used in the manufacturing, fabrication and assembly of components.

• **4.10.1.14.1** If specified, the following alloy steel items shall be subject to PMI testing:

a) the pressure casing of rotating equipment,

b) shafts,

c) blading and shrouds,

d) locking pins used to secure locking buckets,

e) discs of built-up rotors,

f) tie bolts,

g) locking nuts on built up rotors,

h) shaft sleeves,

i) alloy claddings and weld overlays,

j) pressure casing joint bolting (studs and nuts),

k) inlet guide vanes,

l) turbine stationary nozzles,

m) balance pistons.

• **4.10.1.14.2** Any additional PMI testing, in addition to 4.10.1.14.1 shall be specified.

4.10.1.14.3 Mill test reports, material composition certificates, visual stamps, or markings shall not be considered as substitutes for PMI testing.

4.10.1.14.4 PMI results shall be within the governing material standard limits with allowance for the accuracy of the PMI device as specified by the device manufacturer.

4.10.1.15 Unless specified otherwise by purchaser or legislative requirements, nondestructive examination (NDE) of materials shall be in accordance with Section V of the ASME Code.

NOTE The European Pressure Equipment Directive has additional NDE requirements beyond those of ASME.

4.10.2 Castings

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

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

4.10.2.3 Pressure-containing ferrous castings shall not be repaired, except as specified in 4.10.2.3.1 and 4.10.2.3.2.

4.10.2.3.1 Weldable grades of steel castings shall be repaired using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as Section VIII, Division 1, and Section IX of the ASME Code. After major weld repairs and before hydrotest, the complete repaired casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.

4.10.2.3.2 Cast gray iron may be repaired by plugging within the limits specified in ASTM A278, ASTM A395, or ASTM A536, or other internationally recognized standards approved by the purchaser. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

4.10.2.3.3 All repairs that are not covered by ASTM specifications or other internationally recognized standards shall be approved by the purchaser.

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

4.10.2.5 Ductile (nodular) iron castings shall be produced in accordance with ASTM A395 or other internationally recognized standards approved by the purchaser. The production of the castings shall conform to the conditions specified in 4.10.2.5.1 through 4.10.2.5.5.

4.10.2.5.1 A minimum of one set (three samples) of Charpy V-notch impact specimens at one third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y-block. All three specimens shall have an impact value not less than 12.0 J (90 ft-lb) and the mean of the three specimens shall not be less than 14 J (10 ft-lb) at room temperature.

4.10.2.5.2 The keel or Y-block cast at the end of the pour shall have a thickness not less than the thickness of critical sections of the main casting. This test block shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules under microscopic examination shall be in accordance with ASTM A247 or other internationally recognized standards approved by the purchaser.

NOTE Critical sections are typically heavy sections, section changes, high-stress points, and flanges. Normally, bosses and similar sections are not considered critical sections of a casting. If critical sections of a casting have different thicknesses average size keel or Y-blocks may be selected in accordance with ASTM A395.

4.10.2.5.3 Integrally cast test bosses, preferably at least 25 mm (1 in.) in height and diameter, shall be provided at critical areas of casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, high-stress points such as drilled lubrication points, flanges and other points agreed upon by the purchaser and the vendor. Classification of graphite nodules shall be in accordance with ASTM A247 or other internationally recognized standards approved by the purchaser.

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

4.10.2.5.5 Brinell hardness tests shall be made on the actual castings at feasible critical sections such as section changes and flanges. Sufficient surface materials shall be removed before hardness tests are made to eliminate any skin effects. Tests shall also be made at the extremities of the casting at location that represent the sections poured first and last. These shall be made in addition to hardness test on keel or Y-blocks in accordance with 4.10.2.5.1.

4.10.3 Forgings

Compressor and turbine disk forgings shall have transition temperatures (at the bore sections) that are below minimum specified ambient temperatures (see 4.1.19).

4.10.4 Welding

4.10.4.1 Welding of piping, rotating parts and other highly stressed parts, weld repairs and any dissimilar-metal welds shall be performed and inspected by operators and procedures qualified in accordance with Section VIII, Division 1, and Section IX of ASME Code or purchaser-approved standard such as EN 287 and EN 288 for weld qualifications or procedures.

4.10.4.2 Unless otherwise specified, other welding, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with AWS D1.1 or Section IX of the ASME Code or other purchaser-approved welding standard.

4.10.4.3 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedure (see 4.10.1.11).

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

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

4.10.4.6 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 4.10.4.6.1 through 4.10.4.6.4.

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

● **4.10.4.6.2** Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after postweld heat treatment. If specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

4.10.4.6.3 Pressure-containing welds, including welds of the case to axial and radial joint flanges, shall be full-penetration welds.

4.10.4.6.4 Casings fabricated from material that, according to internationally recognized standards such as Section VIII, Division 1, of the ASME Code, require postweld heat treatment shall be heat treated regardless of thickness.

4.10.4.7 Connections welded to pressure casings shall be installed as specified in 4.10.4.7.1 through 4.10.4.7.5.

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

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

4.10.4.7.3 Postweld heat treatment, when required, shall be carried out after all welds, including piping welds, have been completed.

4.10.4.7.4 If specified, proposed connection designs shall be submitted for approval before fabrication. The drawing shall show weld design, size, materials, and preweld and postweld heat treatments.

4.10.4.7.5 All welds shall be heat treated in accordance with internationally recognized standards such as Section VIII, Division 1, UW-19 and UW-40, of the ASME Code.

4.10.5 Impact Test Requirements

● **4.10.5.1** To avoid brittle failures, materials and construction for low-temperature service shall be suitable for the minimum design metal temperature in accordance with the codes and other requirements specified. The purchaser and the vendor shall agree on any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning and testing. Care shall be taken in the selection of fabrication methods, welding procedures, and materials for vendor furnished steel pressure retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for materials manufactured in accordance with the ASME Code and ANSI standards or other internationally recognized standard as approved by the purchaser are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi-killed, fully killed hot-rolled and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices. The vendor should exercise caution in the selection of materials intended for services between –30 °C (–20 °F) and 40 °C (100 °F).

4.10.5.2 All pressure-containing components including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of Section VIII, Division 1, Section USC-65 through 68, of the ASME Code. High-alloy steels shall be tested in accordance with Section VIII, Division 1, Section UHA-51, of the ASME Code. Impact testing is not required if the requirements of Section VIII, Division 1, Section UG-20F, of the ASME Code are met.

Nominal thickness for castings as defined in Section VIII, Division 1, Paragraph UCS-66(2), of the ASME Code shall exclude structural support sections such as feet or lifting lugs. The results of the impact testing shall meet the minimum impact energy requirements of Section VIII, Division 1, Section UG-84, of the ASME Code. The vendor shall specify in the proposal if an alternate code is used.

● **4.10.5.3** The purchaser shall specify the minimum design metal temperature and concurrent pressure used to establish impact test requirements and other material requirements.

4.11 Nameplates and Rotational Arrows

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

4.11.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location.

4.11.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (UNS N04400) alloy. Attachment pins shall be of the same material. Welding is not permitted.

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

a) vendor's name,

b) serial number,

c) model,

d) site rated power and speed,

e) site rated temperature,

f) site rated inlet pressure,

g) site rated exhaust pressure,

h) site rated firing temperature,

i) lateral critical speeds (see note),

j) maximum continuous speed,

k) overspeed trips,

l) fuel types.

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

4.12 Quality

Refer to ISO 9001 for guidelines on improving the quality of equipment.

5 Accessories

5.1 Starting and Helper Driver

5.1.1 General

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

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

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

5.1.1.2 Starting steam turbines shall be termed "general-purpose turbines" in accordance with API 611.

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

● **5.1.1.4** Starter and helper motor drives shall conform to API 541, API 546, or IEC 60034-1, as specified. Since IEC 60034-1 is silent on mechanical design criteria of motors, the above API standards shall prevail for mechanical design for these applications. Motors rated at 375 kW (500 hp) and above shall be in accordance with API 541. Motors rated between 190 kW (250 hp) and 375 kW (500 hp) shall be in accordance with API 547. Motors that are below the power scope of API 547 shall be in accordance with IEEE 841.

● **5.1.1.5** The motor's starting torque shall meet the requirements of the driven equipment, at a reduced voltage of 80 % of the normal voltage, or such other value as may be specified, and the motor shall accelerate to full speed within 15 seconds or such other period of time agreed upon by the purchaser and the vendor.

NOTE Variable frequency-driven (variable speed) speed motors are typically used. These systems have specific electrical requirements for their successful operation.

5.1.1.6 The purchaser shall specify the applicable specifications and standards for other types of starting and helper drivers.

● **5.1.1.7** The turbine vendor shall supply any clutches, speed-changing gears, torque converters, or other power transmission equipment, including controls required or specified for the starting and helper drivers. Gears in continuous service shall be in accordance with API 613 and gears in intermittent service shall be in accordance with API 677.

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

5.1.1.8.1 Jack screws shall be plated for rust resistance.

5.1.1.8.2 Equipment feet shall be drilled with pilot holes that are accessible for use in final dowelling.

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

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

5.1.2 Ratings

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

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

5.1.3 Turning Equipment

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

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

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

5.2 Gears, Couplings, and Guards

5.2.1 Gears

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

5.2.1.2 Load gears and helper driver gears shall be separate coupled units and shall comply with API 613. Epicyclical gears shall be in accordance with AGMA 6123-B06.

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

5.2.1.4 The auxiliary drive gear rotors shall be rated for at least 110 % of the power developed by any starting and helper driver motors connected to them. Auxiliary equipment mating gear rotors shall be rated for 110 % of the maximum power applied to them.

5.2.2 Couplings and Guards

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

5.2.2.2 All couplings shall be dry, flexible diaphragm or disc pack type.

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

● **5.2.2.4** Coupling, coupling-to-shaft junctures, and guards shall conform to ISO 10441. If specified, couplings for speeds below 4000 revolutions per minute can be designed to ISO 14691. Couplings shall be sized to ISO 10441 except as modified by 5.2.2.1 to 5.2.2.3. The make, type, and mounting arrangement of couplings and coupling guards, including vents and drains, shall be agreed upon by the purchaser and the vendors of the driver and driven equipment.

NOTE For the purpose of this provision, API 671 is identical to ISO 10441.

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

5.3 Mounting Plates

5.3.1 General

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

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

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

a) They shall extend at least 25 mm (1 in.) beyond the outer three sides of the equipment feet.

b) They shall have each mounting surface machined within a flatness of 40 μm per linear meter (0.0005 in. per linear foot) of mounting surface.

c) Mounting surfaces for each piece of piece of equipment shall be machined in the same horizontal plane within 25 μm (0.001 in.) to prevent soft foot.

d) Mounting planes for different equipment shall be machined parallel to each other within 50 μm (0.002 in.).

NOTE This may be difficult to achieve with offshore installations without gimbled three-point mounts.

e) The upper and lower surfaces of mounting plates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 3.2 μm (125 μin.) R_a or better.

NOTE For noncritical surfaces, 6 μm (250 μin.) R_a is acceptable.

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

5.3.1.2.3 Machinery supports shall be designed to limit the relative displacement of the shaft end caused by the worst combination of pressure, torque, and allowable piping stress to 50 μm (0.002 in.) at the coupling flange.

5.3.1.2.4 When pedestals or similar structures are provided for centerline supported equipment, the pedestals shall be designed and manufactured to permit the machine to be moved by using the horizontal jackscrews.

5.3.1.2.5 Unless otherwise specified, epoxy grout shall be used for machines mounted on concrete foundations. The vendor shall blast-clean in accordance with ISO 8501 Grade Sa2 (SSPC SP6), all grout contact surfaces of the mounting plates and coat those surfaces with a primer compatible with epoxy grout.

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

5.3.1.2.7 Mounting plates shall conform to the following.

a) Mounting plates shall not be drilled for equipment to be mounted by others.

b) Mounting plates shall be supplied with leveling screws.

c) Outside exposed corners of mounting plates which are in contact with the grout shall have 50 mm (2 in.) minimum radiused outside corners (in the plan view). See Figure 6, Figure 7, Figure 8, and Figure 9. The bottom embedded corners shall be chamfered or radiused.

d) All machinery mounting surfaces shall be treated with a rust preventive immediately after machining.

5.3.1.2.8 The alignment shims shall be provided by the vendor in accordance with API 686, Chapter 7, and shall straddle the hold-down bolts and vertical jackscrews and be at least 6 mm ($^1/_4$ in.) larger on all sides than the equipment feet. If the equipment is factory aligned and mounted to its baseplate as a single skid, shim packs may not be required between the machinery and the baseplate.

5.3.1.2.9 Anchor bolts shall be furnished by the purchaser, unless otherwise specified.

5.3.1.2.10 Hold-down bolts used to attach the equipment to the mounting plates and all jackscrews, shall be supplied by the vendor.

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

5.3.2 Baseplate

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

NOTE A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) is oversize and may have to be fabricated in multiple sections because of shipping restrictions.

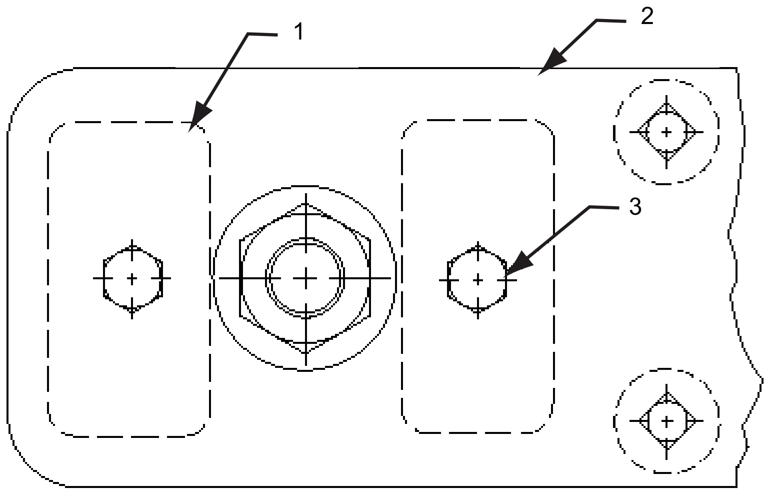
5.3.2.2 When a baseplate(s) is provided, it shall extend under the drive-train components so that any leakage from these components is contained within the baseplate. All joints, including deck plate to structural members, shall be continuously seal-welded on both sides to prevent crevice corrosion. Stitch welding, top or bottom, is unacceptable. All baseplates shall be fully self draining. No areas of the baseplate shall allow standing liquid to collect.

● **5.3.2.3** If specified, the baseplate shall be designed to facilitate the use of optical, laser based, or other instruments for accurate leveling in the field. The details of such facilities shall be agreed by the purchaser and vendor. Where the requirement is satisfied by the provisions of leveling pads and/or targets, they shall be accessible with the baseplate on the foundation and the equipment mounted. Removable protective covers shall be provided. Leveling pads or targets shall be located close to the machinery support points. When required for long units, additional pads shall be located at intermediate points.

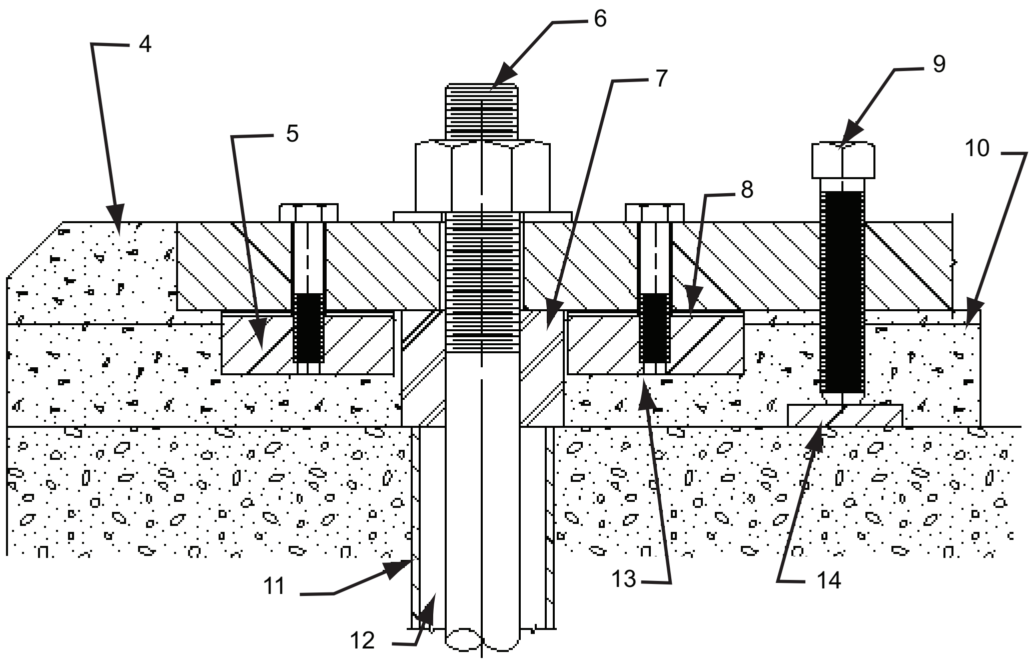
● **5.3.2.4** If specified, the baseplate shall be designed for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

5.3.2.5 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting lugs attached to the equipment shall be designed using a maximum allowable stress of one-third of the specified minimum yield strength of the material. Welding applied to lifting lugs shall be full penetration, continuous welds and be in accordance with ISO 15614 (Annex ZA) or ANSI/AWS D1.1. The welds shall be 100 % NDE tested in accordance with the applicable code. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

5.3.2.6 The bottom of the baseplate between structural members shall be open. If the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 0.01 m^2 (20 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit grouting under all



Top View of Foundation at Foundation Bolt

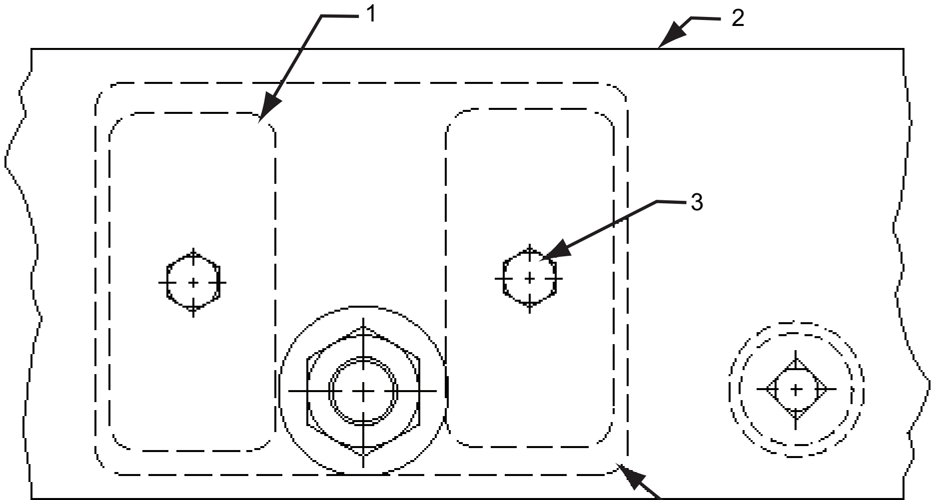


Cross-section of Foundation at Foundation Bolt

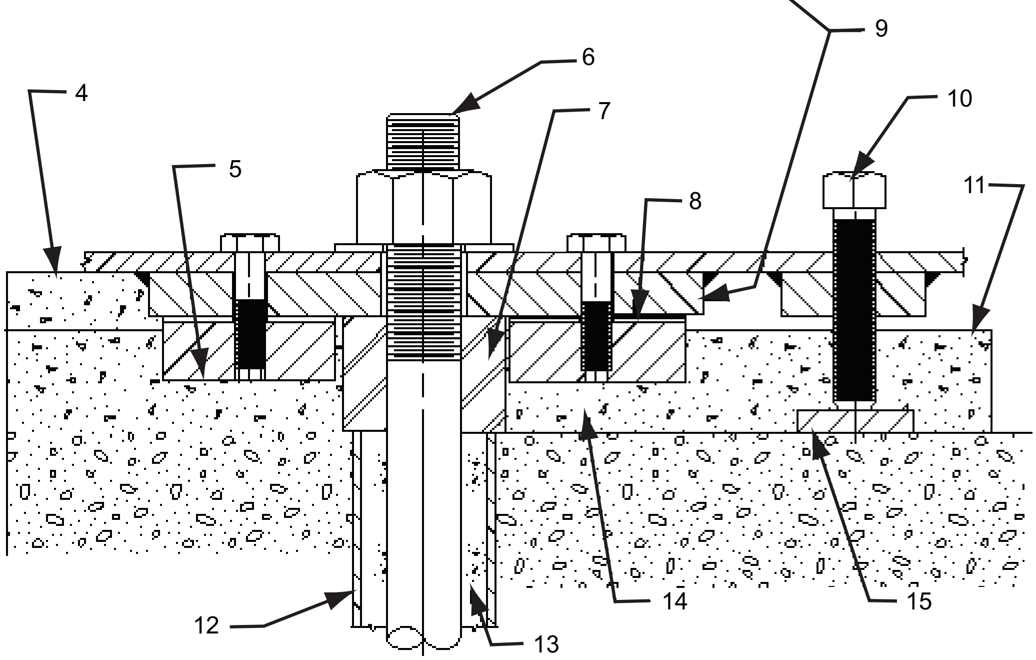
Key

1 subplate
2 soleplate
3 capscrew
4 final grout level after shimming is complete
5 subplate
6 anchor bolt
7 anchor bolt sleeve grout seal
8 shims
9 leveling jackscrew
10 grout level for shim access
11 anchor bolt sleeve
12 nonbonding fill
13 epoxy grout
14 levelling plate

Figure 6—Typical Mounting Plate Arrangement



Top View of Foundation at Foundation Bolt

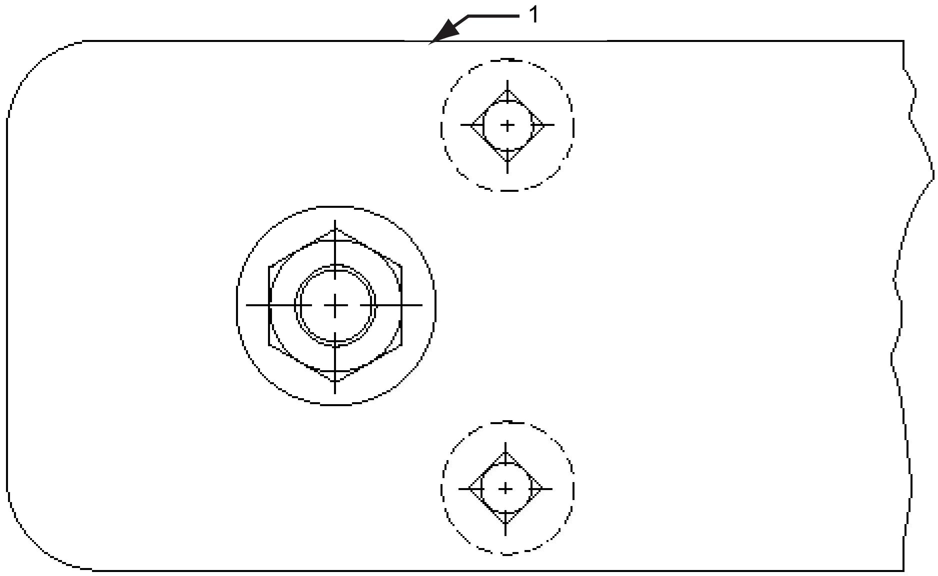


Cross-section of Foundation at Foundation Bolt

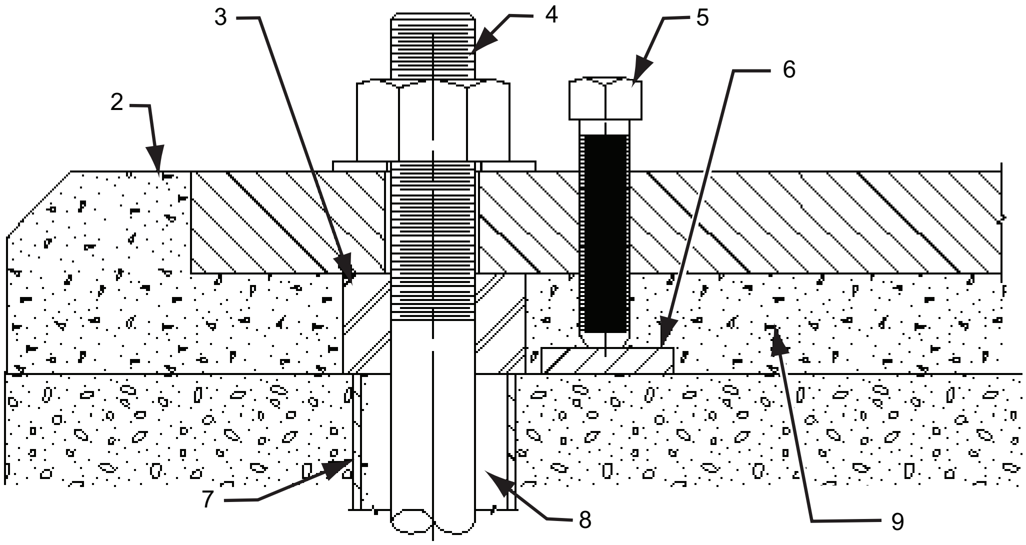
Key

1 subplate
2 baseplate beam
3 capscrew
4 optional full bed grout level
5 subplate
6 anchor bolt
7 anchor bolt sleeve grout seal
8 shims
9 baseplate mounting pad
10 levelling jackscrew
11 grout level for shim access
12 anchor bolt sleeve
13 nonbonding fill
14 epoxy grout
15 levelling plate

Figure 7—Typical Mounting Plate Arrangement



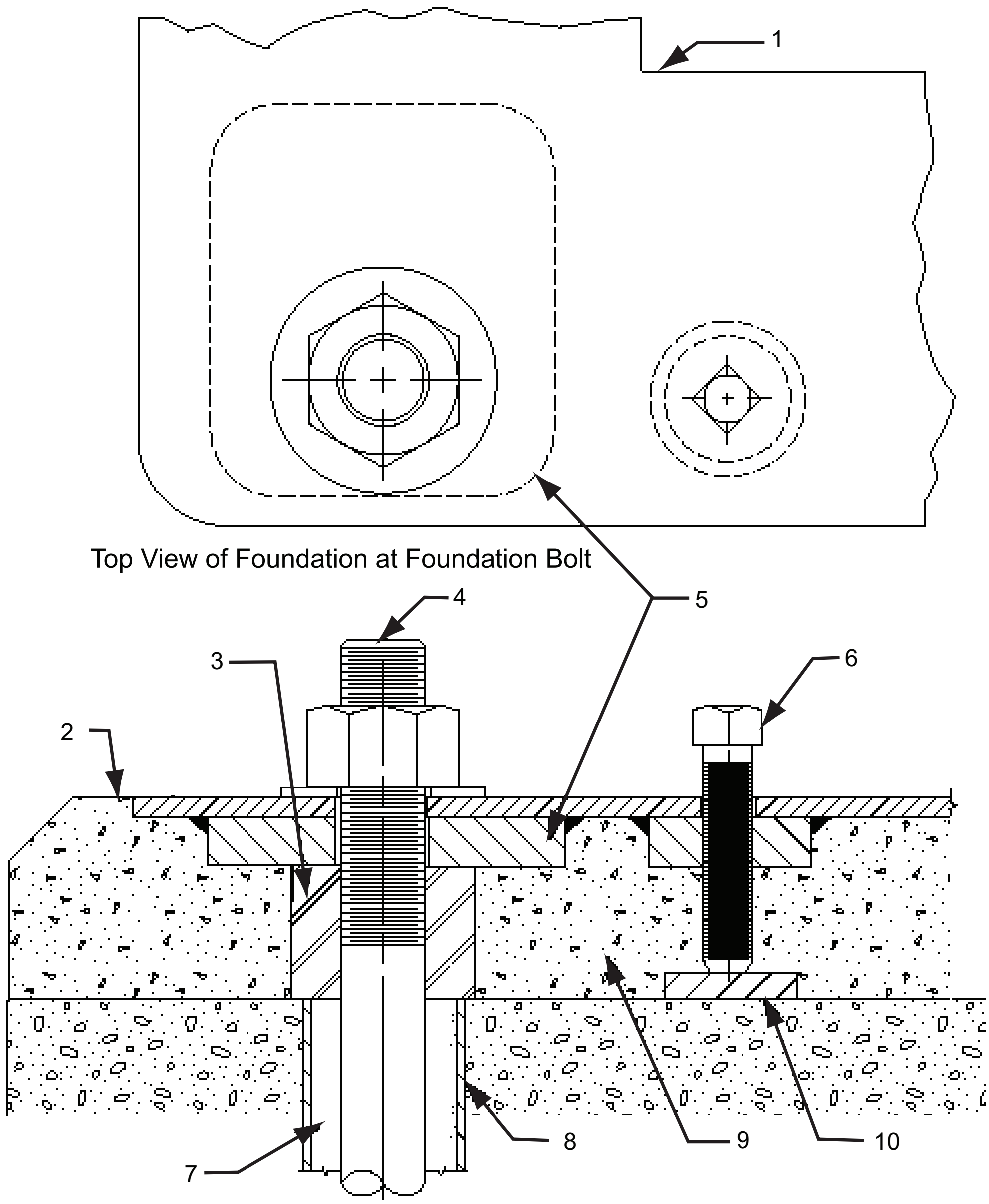
Top View of Foundation at Foundation Bolt



Cross-section of Foundation at Foundation Bolt

Key
1 soleplate
2 grout level
3 anchor bolt sleeve grout seal
4 anchor bolt
5 levelling jackscrew
6 levelling plate
7 anchor bolt sleeve
8 nonbonding fill
9 epoxy grout

Figure 8—Typical Mounting Plate Arrangement



Top View of Foundation at Foundation Bolt

Cross-section of Foundation at Foundation Bolt

Key

1 baseplate beam
2 grout level
3 anchor bolt sleeve grout seal
4 anchor bolt
5 baseplate mounting pad
6 levelling jackscrew
7 nonbonding fill
8 anchor bolt sleeve
9 epoxy grout
10 levelling plate

Figure 9—Typical Mounting Plate Arrangement

load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed. The holes shall have 13 mm ($^1/_2$ in.) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 3 mm ($^1/_8$ in.) shall be provided.

5.3.2.6.1 Vent holes at least 13 mm ($^1/_2$ in.) in size shall be provided at the highest point in each bulkhead section of the baseplate.

5.3.2.6.2 Grout shall form a continuous seal around the periphery of the baseplate, to ensure water ingress is avoided which could lead to corrosion.

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

5.3.2.8 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate. The metal decking shall allow free drainage. It shall be checkered plate or grating having a raised pattern. The decking shall be covered with a nonskid coating or grating.

5.3.2.9 All upper baseplate mounting surfaces shall meet the following criteria.

a) They shall be machined after the baseplate is fabricated.

b) They shall be machined to a finish of 6.3 µm (250 µin.) R_a or better.

c) They shall have each mounting surface machined within a flatness of 40 µm per linear meter (0.0005 in. per linear foot) of mounting surface.

d) Mounting surfaces for each piece of equipment shall be machined in the same horizontal plane within 25 µm (0.001 in.) to prevent a soft foot.

e) Mounting planes for different equipment shall be machined parallel to each other within 50 µm (0.002 in.).

NOTE The tolerances in 5.3.2.9 shall be recorded and verified by placing the baseplate in unrestrained condition on a flat machined surface at the place of its manufacture.

5.3.3 Soleplates and Subsoleplates

• **5.3.3.1** If soleplates and/or subsoleplates have been specified to be provided by the vendor, they shall meet the requirements of 5.3.3.1.1 and 5.3.3.1.2 in addition to those of 5.3.2.

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

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

5.3.3.2 Subsoleplates shall be steel plates at least 25 mm (1 in.) thick. The finish of the subsoleplates' mating surfaces shall match that of the soleplates (see 5.3.1.2.1).

5.4 Controls and Instrumentation

5.4.1 General

• **5.4.1.1** Instrumentation and installation shall conform to the requirements of ISO 10438, API 614, or purchaser's specifications as specified.

5.4.1.2 Unless otherwise specified, controls and instrumentation shall be designed for outdoor installation and shall meet the requirements of IP 66 as detailed in IEC 60529 or NEMA 4X as detailed in NEMA Publication 250. Equipment located indoors shall have a rating suitable for the environment.

5.4.1.3 Where applicable, controls and instrumentation shall conform to API 551, Part 1, and API 670.

5.4.1.4 Terminal boxes shall be IP 66 as detailed in IEC 60529 or NEMA 4X as detailed in NEMA Publication 250. Unless otherwise specified, terminal boxes shall be made of 316L stainless steel.

5.4.1.5 The purchaser shall specify (see 4.1.14) the hazardous electrical area classification (class, group, and division or zone) where the gas turbine package will be installed. The vendor determines the hazardous electrical area inside the gas turbine package and shall advise the purchaser of any external hazardous areas generated by the package.

5.4.1.5.1 Locations for installed equipment can be classified as hazardous electrical areas or they can be unclassified. An unclassified area is considered nonhazardous therefore, motors, electrical instrumentation, equipment, components, and electrical installations for unclassified areas are not governed by hazardous area electrical codes.

5.4.1.5.2 If an installation location is classified as hazardous (see 4.1.14), motors, electrical instrumentation, equipment, components, and electrical installations shall be suitable for the hazardous electrical area classification designation as specified. Mechanical equipment shall be assessed for its inherent capability to produce ignition sources, e.g., hot surface temperatures and sparking of rotating components.

• **5.4.1.5.3** All applicable electrical codes shall be specified by the purchaser. Local electrical codes that apply shall be provided by the purchaser upon request.

5.4.1.5.4 Electrical codes vary by installation location. Refer to Table 5 for a tabulation of common hazardous area electrical codes in use.

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

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

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

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

Table 5—Common Hazardous Area Electrical Codes

Standards Org.	Codes	Where Used	Hazardous Electrical Area Classification Designation
IEC, CENELEC	IEC 60079, EN 60079	EU countries and worldwide, except United States	Zone, Gas Group, Temperature Class
European Union (EU)	ATEX Directive 94/9/EC	Required, in addition to IEC, in EU countries only. May be requested in other countries.	Equipment Group, Category
NEC®	NFPA 70, Sections 500 to 502, 504	United States	Class, Division, Group, Temperature Class
NEC®	NFPA 70, Section 505	United States	Class I, Zone, Gas Group, Temperature Class
CEC®	CSA C22.1-06, Section 18	Canada	Primary: Adoption of IEC—Zone, Gas Group, Temperature Class In Appendix: Class, Division, Group, Temperature Class

IEC International Electrotechnical Commission
CENELEC European Committee for Electrotechnical Standardization
ATEX *Atmospheres Explosibles*, *Equipment intended for use in Potentially Explosive Atmospheres*
NEC® National Electrical Code®, published by National Fire Protection Association, Inc. (NFPA)
CEC® Canadian Electrical Code®, published by Canadian Standards Association (CSA)

NOTE The ATEX directive, 94/9/EC, became effective on June 30, 2003, and applies to all equipment (mechanical and electrical) that is intended for use in a potentially explosive atmosphere, in the European Economic Area. While not a specific electrical code, it is listed in the table because most electrical products cannot be put into use in a hazardous area in the European Economic Area without ATEX certification. Also, mechanical products, which are used in the EU, in a hazardous area, are required to conform to the ATEX directive. The ATEX directive defines categories, which determine the approach used to obtain ATEX certification. Electrical and mechanical equipment are required to meet the essential health and safety requirements set forth in the ATEX directive.

5.4.2 Control Systems

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

a) semi-automatic start, if specified, shall require manual activation of the accessories and auxiliaries and shall permit the operator to commit the turbine to the complete starting sequence by a single action;

b) automatic start shall require only a single action by the operator to activate auxiliary equipment and initiate the complete sequence.

5.4.2.2 Control systems shall allow a purge period of sufficient duration to permit the displacement of the volume of the entire exhaust system (including the stack).

NOTE Additional guidance can be sought in ISO 21789 and in 5.4.2.2.1 to 5.4.2.2.5.

5.4.2.2.1 The exhaust system shall be purged before gas turbine start-up. The purge flow rate should be sufficient to minimize un-purged voids. At least three complete volume changes of the gas turbine and downstream exhaust system equipment shall be undertaken, measured up to the base of any main chimney or a point where, under all load conditions, the exhaust gas temperature is below 80 % of the auto ignition temperature (AIT) measured in degrees Celsius of any flammable gases or vapors that may be present. Attention shall be given to the potential for entrainment, reentry or collection of heavier than air gases.

5.4.2.2.2 The required air purge volume shall be proven by the use of appropriate instrumentation interlocked to the start-up sequence. Where the gas turbine air compressor itself is used to provide the purge flow, proof of adequate gas turbine compressor rotation speed shall be used to verify the flow rate.

5.4.2.2.3 The fuel used for start-up shall be such that auto-ignition on hot internal surfaces does not lead to dangerous overpressure conditions or uncontained component failure. This would typically apply to fuels such as naphtha where significant potential exists for the formation of large potentially explosive vapor clouds.

5.4.2.2.4 Where more than one gas turbine supplies a heat recovery system, precautions should be taken to ensure that reverse exhaust gas flows cannot pass back into another gas turbine under any purge, start-up or other flow condition.

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

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

5.4.2.5 Under normal shutdowns, the control system shall provide a means to systematically cool down the gas turbine to prevent rotor bow or blade tip rubs on a subsequent start-up. If a turning gear or racheting device is provided, it shall be automatically engaged by the control system at the end of the normal shutdown.

5.4.2.6 If the starting fuel is different from the normal fuel, starting shall be accomplished using the same fuel control system.

5.4.3 Load Control

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

5.4.3.2 For a variable-speed drive, the control signal shall act to adjust the set point of the driver's speed-control system. Unless otherwise specified, the control range shall be at least from 5 % above to 5 % below the output shaft operating speed range specified in 4.1.5 or as mutually agreed to between purchaser and vendor.

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

5.4.3.4 The governor for mechanical drive applications shall limit speed to 105 % of rated speed under normal operating conditions.

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

5.4.3.6 Governor systems shall prevent the gas turbine from tripping on overspeed when an instantaneous loss of electric, hydraulic, or aerodynamic load occurs. A safe, controlled shutdown may occur in the event of hydraulic or load loss for safety reasons.

5.4.4 Alarms and Shutdowns

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

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

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

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

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

5.4.4.3 Fuel control system shall include the valving detailed in 5.8.

5.4.4.4 Fuel system venting shall be as detailed in 5.8.

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

5.4.4.6 An overspeed trip protection shall operate at 105 % of maximum continuous speed for mechanical drive applications. Generator drive applications can have an overspeed trip setting lower than 105 % of maximum continuous speed. Multiple-shaft turbines shall have individual overspeed trip protection for each shaft.

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

5.4.4.7.1 Annunciated alarm and shutdown conditions shall include those listed in Table 6.

5.4.4.7.2 If an alarm function in addition to a shutdown function is specified, the alarm shall be set to precede the shutdown so that corrective action may be taken.

• **5.4.4.8** Alarm and shutdown arrangements shall be in accordance with ISO 10438 as specified. Additional requirements are described in 5.4.4.8.1 to 5.4.4.8.8.

NOTE API 614 is identical to ISO 10438.

• **5.4.4.8.1** If alarm and shutdown switches are specified, they shall be single-pole, double throw design.

5.4.4.8.2 All circuits shall be fail-safe. Devices shall open to annunciate alarm or trip as appropriate.

NOTE Switches connected to open (de-energize) are normally considered to be fail safe.

5.4.4.8.3 If switches are used for alarm and trip functions then switch settings shall not be adjustable from outside the housing. Pressure elements shall normally be of 18-8 stainless steel, but shall be compatable to the system fluids at all forseeable operating conditions. Alarm and shutdown switches shall be arranged to permit testing of the control circuit, including the actuating element where possible, without interfering with normal operation of the equipment.

Table 6—Typical Alarm and Shutdown Annunciation

Condition	Alarm Annunciated	Shutdown
radial shaft vibration	X	X [a]
axial thrust position	X	X [a]
overspeed	X	X
casing vibration	X	X [a]
high thrust or radial bearing temperature	X	
low fuel supply pressure	X	X
turbine exhaust overtemperature	X	
failure of exhaust overtemperature shutdown device	X	
high differential pressure in each air inlet filter	X	
combustor-stage flameout	X	X
control system failure	X	X
failure of starting clutch to engage or disengage	X	
low lube-oil pressure	X	
high or low lube-oil reservoir level	X	
lube-oil filter differential pressure	X	
lube-oil spare pump operation	X	
low control-oil pressure	X [a]	
other protective devices on turbine auxiliaries	X	
other process or driven equipment functions	X	X [a]

[a] Optional.

The vendor shall provide a clearly visible light on the panel to indicate if trip circuits are in the test bypass mode.

Low-pressure alarms shall be equipped with valved bleed or vent connections to allow controlled depressurizing so that the operator can note alarm set pressure on the associated pressure gauge. Similarly, high-pressure alarms shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure. In addition, shutdown systems shall be provided with electrical disconnect switches or other suitable means to permit testing without shutting down the unit. The vendor shall furnish with the proposal complete descriptions of the alarm and shutdown testing facilities to be provided, together with any critical services that are not supplied with bypass facilities.

5.4.4.8.4 An audible alarm such as a bell, horn or annunciator that will be actuated by the alarm or shutdown relay shall be provided on the control panel.

● **5.4.4.8.5** If specified, in addition to the control system screen, the vendor shall furnish a first-out annunciator when an annunciator system is specified.

a) The annunciator shall contain approximately 20 % spare points to cover available optional equipment.

● b) If specified, the annunciator shall be suitable for purging.

5.4.4.8.6 Alarm indication shall be via an audible alarm at the control system interface and an associated flashing message and by a flashing light and the sounding of a horn or another audible device when associated with a Fire and Gas function.

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

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

• **5.4.4.9** Unless otherwise specified, the necessary valving and switches or bridging links (jumpers) or other approved protocol shall be provided to enable all instruments and other components, except shutdown sensing devices, to be replaced with the equipment in operation. If specified, shutdown sensing devices shall be provided with isolation valving, bridging links or other approved protocol to allow replacement with the equipment in operation.

• **5.4.4.10** If isolation valves for shutdown sensing devices are specified, the vendor shall provide means of locking the valves in the open position.

5.4.4.11 A listing of devices that cannot be changed on line or that cannot be supplied with a lock-open facility shall be provided in the proposal.

5.4.5 Instrumentation and Control Panels

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

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

a) free standing consoles shall be suitable for installation in a nonhazardous, indoor area,

b) package skid mounted consoles shall be suitable for the same area classification as applied to the skid,

c) the control system shall be microprocessor based,

d) the console shall allow space for the package supplier to mount instruments provided by the purchaser in/on the console as mutually agreed during the proposal.

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

5.4.5.1.2 It is preferred that the control system be of a design that has been proven by experience of having been installed in at least three (3) similar applications and that the system has a total of 10,000 operating hours of service, and that the system and configuration being provided represent the supplier's standard equipment.

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

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

5.4.5.3 Wiring to switches and instruments on the unit shall be from a minimum number of terminal boxes mounted at each skid edge. Terminal boxes are to be mounted so they are not disturbed during routine maintenance. Any purchaser connections shall be defined and wire type and route / entry details to the terminals agreed. Wire splices are not allowed.

5.4.5.3.1 All leads and posts on terminal strips, devices and instruments shall be tagged for identification, using a mutually agreed system.

● **5.4.5.3.2** Control and instrumentation wiring, that is not within a fully enclosed panel or other enclosure, shall be in the form of armored cable or shall be run in metal conduit as specified.

5.4.5.3.3 If armored cable is used, it shall be installed as follows:

a) armored cable shall be supported on cable tray;

b) the cable tray shall be manufactured from material suitable to last the design life of the equipment under all foreseeable operation conditions;

c) cable tray shall have sufficient rigidity to withstand a 900 N (200 lbf) static point load without damage;

d) cable glands shall be certified for the hazardous area they are installed within;

e) low-smoke, non-PVC sheathed cables shall be provided;

f) power and Instrument cables shall not be installed adjacent to each other but may share the same tray if separation distances are maintained;

g) integrity of cable shields shall be maintained at junction boxes.

5.4.5.3.4 Conduit shall be properly supported to avoid damage caused by vibration and isolated and shielded to prevent interference between different services. Conduits may terminate (in the case of the leads to temperature elements, shall terminate) with a length of flexible metal conduit, long enough to facilitate maintenance without removal of the conduit. If temperature element heads are exposed to temperatures above 60 °C (140 °F), a flexible metal conduit shall be used.

5.4.5.3.5 All control cabinets designed to be outdoors, and that contain electrical contacts, relays, or instruments, shall have provisions for dry air purge to prevent contamination and corrosion. Dry air will be furnished by the purchaser.

5.4.6 Electrical Systems

● **5.4.6.1** The characteristics of electrical power supplies for motors, heaters, and instrumentation shall be specified by the purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. Unless otherwise specified, the pilot lights shall be installed on the motor control centers, power distribution control panels and or any uninterrupted power supplies (UPS). As an alternative to pilot lights, an alarm could be initiated if any of the power supplies is cut off.

5.4.6.2 Electrical equipment located on the unit or on any separate panel shall be suitable for the hazard classification specified (see 4.1.14). Electrical starting and supervisory controls may be either AC or DC. Additional precautions may be required for installation in zoned areas. A ventilated enclosure around the gas turbine to mitigate the risk of explosion or fire, even if properly certified equipment is used, may be required.

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

5.4.6.4 Unless otherwise specified, all leads on terminal strips, switches, and instruments shall be permanently tagged for identification.

All terminal boards in junction boxes and control panels shall have approximately 20 % spare terminal points.

5.4.6.5 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on turbine and auxiliary equipment. The clearances required for 600-volt service shall also be provided for lower voltages or clearances shall meet the requirements of IEC 60204-1. To guard against accidental contact, enclosures shall be provided for all energized parts.

• **5.4.6.6** Electrical materials including insulation shall be corrosion resistant and nonhygroscopic insofar as is possible. If specified for tropical location, materials shall be given the treatments specified in 5.4.6.6.1 and 5.4.6.6.2.

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

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

5.4.6.7 Control, instrumentation, and power wiring (including temperature element leads) within the limits of the baseplate shall be protected against damage by being installed in metallic conduits or in mechanically protected areas or shall be suitably sheathed/braided and properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit.

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

NOTE For Division 2, nonjacketed flexible cable (BX cable) can be provided.

5.4.6.9 AC and DC circuits shall be clearly labeled, identifiable by color coding of the individual wires and connected to separate terminal blocks, and isolated from each other. Local legislation may dictate colors to be used.

5.4.7 Instrumentation

5.4.7.1 General

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

5.4.7.2 Tachometers

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

● **5.4.7.2.2** The type of tachometer will be specified. Unless otherwise specified, the minimum range shall be from 0 % to 125 % of the maximum continuous speed (in revolutions per minute).

5.4.7.3 Temperature Gauges

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

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

5.4.7.4 Thermowells

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

● **5.4.7.5 Thermocouples and Resistance Temperature Detectors (RTDs)**

Where practical, the design and location of thermocouples and RTDs shall permit replacement while the unit is operating. The lead wires of thermocouples and RTDs 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. If specified, monitors shall be supplied, installed, and calibrated in accordance with API 670.

● **5.4.7.6 Pressure Gauges**

Pressure gauges (not including built-in instrument air gauges) shall be furnished with AISI Standard Type 316 stainless steel bourdon tubes and stainless steel movements for most duties. Materials shall be selected to suit the working fluids. A minimum of 110-mm ($4^1/_2$-in.) dials, 152-mm (6-in.) dials for the range over 55 bar (800 psi), and NPT $^1/_2$ male alloy steel connections. Black printing on a white background is standard for gauges. If specified, oil-filled gauges or other snubbing device shall be furnished. 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 %. Each pressure gauge shall be provided with a device such as a disk insert or blowout back designed to relieve excess case pressure.

5.4.7.7 Solenoid Valves

The use of direct solenoid-operated valves is restricted to small lines of nominal 25 mm (1 in.) or smaller in applications with clean (filtered) working fluids. All solenoid valves shall have Class F insulation or better, and shall have a continuous service rating. If required for other services, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves, and the like.

5.4.7.8 Vibration and Position Detectors

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

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

● **5.4.7.8.3** If specified, casing vibration transducers shall be supplied, installed, and calibrated in accordance with API 670.

● **5.4.7.8.4** If specified, casing vibration monitors shall be supplied and calibrated in accordance with API 670.

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

• **5.4.7.8.6** If specified, monitors for use with casing vibration and rolling element bearings shall be supplied and calibrated in accordance with API 670. If specialized vibration monitors for use with rolling element bearings not covered by API 670 are to be supplied, the vendor shall provide the purchaser with details and specifications for purchaser review.

5.5 Piping and Appurtenances

5.5.1 General

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

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

a) fuel gas and oil,

b) water injection,

c) steam injection,

d) starting air and gas system,

e) instrument and control air,

f) compressor bleed air,

g) cooling water,

h) liquid wash water (on-line or off-line),

i) lubrication oil,

j) control oil,

k) hydraulic oil,

l) drains and vents.

NOTE Piping and tubing mounted on aeroderivative gas generators often follow manufacturers' aircraft design practices and are not considered auxiliary system pipes.

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

5.5.1.4 Pipe plugs shall be in accordance with 4.4.4.

5.5.2 Oil Piping

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

5.6 Inlet and Exhaust Systems

5.6.1 General

5.6.1.1 An inlet and exhaust system consisting of an inlet air filter, inlet and exhaust silencers, inlet and exhaust expansion joints, and inlet and exhaust ducting shall be supplied.

5.6.1.2 The inlet and exhaust systems shall meet the sound pressure level requirements of 4.1.10. Intermittent noise sources, e.g., blowoff systems, shall be considered in the analysis.

5.6.1.3 Connections for sensing pressure at the gas turbine inlet and exhaust flanges shall be included.

5.6.1.4 Unless otherwise specified, the inlet system shall be designed for a maximum total pressure drop of 1 kPa (4 in. water) with a clean air filter and at least 110 % of the air mass flow (including any required ventilation air) at site rated power, ISO power or power at site minimum temperature, whichever is greater.

● **5.6.1.5** Unless otherwise specified, the exhaust system shall be designed for 1.5 kPa (6 in. water) pressure drop when there is no heat recovery system. If a heat recovery system is specified, the system pressure drop shall not exceed 2.5 kPa (10 in. water).

NOTE The economics of individual applications could dictate other design factors for each system that may be used with the purchaser's agreement.

● **5.6.1.6** Requirements of exhaust mounted overpressure protective devices, diversion valves or heat recovery systems shall be specified by the purchaser.

● **5.6.1.7** If specified or if required by the vendor for safe operation (see 5.6.1.8), a duct mounted anti-icing system shall be provided. If an anti-icing system is required, the vendor shall fully describe the system, vendor's scope, effect on engine's performance over the ambient range, and required utilities.

● **5.6.1.8** The purchaser shall specify meteorological data obtained by long-term measurements at site for the gas turbine vendor to use in selecting the inlet system components. Monthly mean wind roses shall be provided for wind speed and direction. Meterological parameters include the following:

a) wind speeds and major wind direction;

b) wind speed and wind direction for the major local and distant contaminant sources noted in 5.6.1.9.2;

c) dry bulb temperature (minimum and maximum), including typical daily variations;

d) barometric pressure;

e) rainfall, including maximum rate;

f) snowfall;

g) relative humidity, seasonal variations and typical daily variations;

h) frequency of fog or mist conditions;

i) frequency of icing conditions (occurrence of temperatures between +5 °C and –5 °C and relative humidity >80 %).

• **5.6.1.9** The purchaser shall specify the air quality as required by 5.6.1.9.1 and 5.6.1.9.2.

NOTE Performance, operability, reliability, availability, expected overhaul intervals, expected maintenance costs, and emissions for the gas turbine and the gas turbine package are all influenced by a variety of parameters, including atmospheric air quality entering the equipment. Knowledge of ambient air quality is important for predicting equipment life, correct filtration system selection, and correct materials selection. In cases where air is not "clean," there can be an impact on equipment life, maintenance intervals, and maintenance costs. Air quality is particularly important with respect to gaseous contaminants, which cannot be removed by filtration.

• **5.6.1.9.1** The purchaser shall specify the following chemical contaminants in the air. The minimum, maximum and average values shall be provided:

a) sodium (Na),

b) potassium (K),

c) calcium (Ca),

d) chloride (Cl^-),

e) sulphate (SO_4),

f) nitrate (NO_3^-),

g) trace metals (e.g., V, Pb, Ni, Zn),

h) sulphur dioxide (SO_2),

i) ammonia (NH_3),

j) nitrous oxides (NO_x),

k) hydrocarbons (VOC),

l) hydrogen sulphide (H_2S),

m) chlorine gas (Cl_2),

n) hydrochloric acid (HCl),

o) neon (Ne),

p) ozone (O_3),

q) helium (He),

r) methane (CH_4),

s) krypton (Kr),

t) hydrogen (H_2),

u) nitrous oxide (N_2O),

v) carbon monoxide (CO),

w) xenon (Xe),

x) nitrogen dioxide (NO_2).

● **5.6.1.9.2** The purchaser shall specify the presence, distance and direction to major local or distant potential sources for contamination as noted in Table 7. Size distribution data shall be provided for particulates.

Table 7—Inlet Air Contaminants and Sources

Potential Source of Contaminants	Potential Contaminants
a) sea water, coastal water	water spray, NaCl
b) dry lake beds	NaCl
c) roads with heavy traffic	particulates, VOC, SO_2, NO_x, chlorides
d) cooling towers at site close to the GT plant	drift, thermal plume
e) petrochemical industry	sulphur compounds, VOC
f) fossil fired power plants	fly ash, coal dust, SO_2
g) general chemical industry	SO_2, HCl, H_2S, NH_3
h) paper and pulp industry	fibers, SO_2, H_2S
i) cement production, quarries	$CaCO_3$, SiO_2
j) agricultural activities	particulates, nitrates, phosphates, seeds, insects, pollen
k) production of fertilizers	ammonia, phosphates, nitrates, calcium
l) mining and metallurgical activities	particulates

5.6.1.10 Unless otherwise specified, the inlet system shall be series 300 stainless steel construction.

5.6.1.11 System components, except for filter media, shall be designed for a useful life of at least 20 years. The purchaser shall specify site conditions as identified in 5.6.1.9 that could affect the system design and the selection of the materials. Provisions shall be made to permit maintenance of inlet filter media during operation of the turbine.

5.6.1.12 All inlet system components downstream of the inlet filter elements shall be designed for a minimum collapse differential pressure of 3 kPa (12 in. water).

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

● **5.6.1.14** If specified, a reinforced coarse-mesh 6.4 mm to 12.7 mm ($^1/_4$ in. to $^1/_2$ in.) stainless steel screen shall be provided immediately ahead of the gas turbine air inlet. The actual location shall be mutually agreed upon by the vendor and the purchaser, both of whom must consider cleaning systems, access plates, viewing windows, vaned elbows, and aerodynamic disturbance of the bellmouth entrance.

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

5.6.1.16 A gas generator compressor and power turbine cleaning system shall be provided. The vendor shall describe the type of compressor cleaning system being provided. The vendor shall address in the proposal features and requirements such as: manual or automatic operation, integral-to-package or separate, solvents, and antifreeze compounds and utilities.

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

5.6.1.18 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 radians).

5.6.1.19 Duct supports shall remove all duct loads from the gas turbine flanges. The ducts shall be supported to allow lateral as well as axial growth due to temperature changes. The ducting and supports shall be designed to remain stationary if sections near the gas turbine are removed to provide access for maintenance. Ducts shall be sufficiently rigid to avoid vibration. Plate that is 5.0 mm to 10.0 mm ($^3/_{16}$ in. to $^3/_8$ in.) thick shall be used for this purpose.

5.6.1.20 Manways shall be provided (if duct size permits) in each duct adjacent to the gas turbine inlet and exhaust flanges to allow final cleaning and inspection of the entire duct system before operation. These may be the same means of access required by 4.2.8. Manway covers shall be designed to permit their removal at any time without risk of fasteners or other objects being ingested by the gas turbine.

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

5.6.1.22 Gastight expansion joints shall be provided between the ducting and gas turbine inlet and exhaust flanges. These joints shall accommodate the relative movement of the ducting, regenerator (if any), and gas turbine in vertical and horizontal directions. Expansion joints shall have an internal liner to prevent undue flutter, joint deterioration, or pressure drop. The joints shall be covered with a sound-absorbing material that will meet the noise-level specifications in 4.1.10.

5.6.2 Inlet Systems

5.6.2.1 Inlet Filters

5.6.2.1.1 Unless otherwise specified, the vendor shall select the type of inlet filtration required to meet site conditions and operational requirements. The filtration system shall be selected to meet the requirements of 5.6.2.2, 5.6.2.3, or 5.6.2.4.

NOTE There are two basic types of air inlet filter systems; static and "self-cleaning" pulse filter systems. Static air filter systems comprise of several filter stages, while "pulse" air filter systems comprise either a single pulse filter stage or an initial pulse filter stage followed by a static fine filter stage. Pulse filter systems are mainly adapted for sites where the ambient air may contain significant amounts of large particles, e.g., in dusty areas. Investigations and practical experiences indicate that the addition of a static fine filter stage after the pulse filter stage often offers better and more reliable filtration than single-stage pulse filters. Addition of a second filter stage after the initial pulse filter stage reduces the risks for penetration of water soluble salts in liquid form during humid conditions. The disadvantage is an increased first cost, mainly because of the need of a large air inlet filter house.

• **5.6.2.1.2** If single-stage filtration only is specified, the purchaser will specify if provisions are to be made for the future addition of extra stages.

5.6.2.1.3 A drain system shall be provided to ensure that any water caught within the air intake is immediately removed, preventing the risk of re-entrainment into the airstream. Drains shall not allow air ingress.

5.6.2.1.4 The filter house shall be supplied with relevant instrumentation for proper alarm and shutdown monitoring of differential pressure. Instrumentation and wiring shall be installed per the required codes and specifications, and wired to terminal strips located in junction boxes mounted on the outside of the filter structure.

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

5.6.2.1.6 The vendor's proposal shall include the filtering efficiency (under clean and dirty conditions) and estimated frequency of maintenance or cleaning (or both) for the specified site conditions (see 5.6.1.9.1 and 5.6.1.9.2). The vendor shall also review the specified filtration and comment on the suitability of filtration for the specified machine.

5.6.2.1.7 Unless otherwise specified, each filter system shall include the following.

a) An entrance screen to prevent debris or birds from entering the inlet.

b) Downward orientation of the air inlet or a louver or cowling to minimize the entry of driving rain, snow, or sand to the filter.

c) Walkways, handrails, platforms, and ladders to facilitate access and maintenance.

d) Manometer connections and a differential-pressure alarm for each filtration stage.

e) Wiring in conduit using conduit fittings (with the exception of joints between modules where using flexible conduit is permitted) or armoured cable system.

f) A design that uses bolted and welded fabricated steel plate, reinforced with steel members. The vendor shall furnish all of the supporting structural steel required for the assembled and mounted filter systems. All external structural steel shall be hot-dipped galvanized, with thickness per ASTM A123 or ISO 1461. All external joints shall be leak proof. Zinc is not permitted in the flow path surfaces downstream of the filters.

g) Modular construction with each module fully factory assembled, with all required wiring, piping and structural supports. Each module shall have lifting provisions that permit it to be loaded, unloaded, and lifted into its final assembled position.

h) Airtight seams and joints on the clean air side of each filter system.

i) The clean air side of the filter assembly is to be completely free of loose objects or objects that can become loose during operation.

• **5.6.2.1.8** If specified, an under pressure protection device (e.g. implosion door) shall be provided to prevent excessively high delta pressure in the turbine inlet in the event of filter icing, or plugging. This device shall be instrumented to provide remote indication when the device is actuated.

• **5.6.2.1.9** Unless otherwise specified, the filter house will be elevated with a minimum 4.6 m (15 ft) elevation from grade to the lowest part of the filter air entrance. If the filter house is elevated, the vendor shall provide lugs for mounting the house to supporting steelwork. The purchaser shall specify if supporting steel work is to be provided by the vendor.

NOTE 1 Consideration should be given to filter units mounted on large horizontal surfaces, such as roofs, to ensure adequate clearance from those mounting surfaces even though the filter may be in excess of the specified 4.6 m (15 ft) above grade.

NOTE 2 Provide consideration for conditions such as snow drifts.

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

● **5.6.2.2 Self-ceaning Filter System**

5.6.2.2.1 The cleaning cycle shall be automatic. The cleaning cycle shall be capable of being adjusted by varying the set points of the differential pressure across the filters or by an adjustable timer.

NOTE A self-cleaning air filter system features media filter cartridges, which are routinely cleaned during normal turbine operation by pulses of pressurized air.

● **5.6.2.2.2** If specified, the vendor shall provide a relative humidity sensor. The sensor shall automatically activate the cleaning cycle when the relative humidity is above 60 %, whether the turbine is running or not.

NOTE High humidity and blowing dust can cause severe caking of material on the filter elements.

5.6.2.2.3 The vendor shall advise all required utilities.

5.6.2.2.4 The module shall be supplied with a manual override and a cycle counter.

5.6.2.3 High-velocity Inlet Filter System

NOTE High-velocity filter systems are usually considered for off-shore or marine applications as an alternative to conventional low-velocity static filter systems. The advantages of high-velocity static filters are lower weight and a smaller footprint at the expense of a higher pressure drop or lower removal efficiency for small particles.

High-velocity static filter barrier systems shall include a primary droplet separator and a minimum of one static particle filter. The droplet separator shall be the vane separator type. Hoods for weather protection and protective screens shall be supplied.

● **5.6.2.3.1** The high-velocity inlet filter system shall consist of three stages. In addition, higher efficiency filters may be added if required by the site conditions.

NOTE A high-velocity filter system is usually designed for an air velocity of 5 m/s (16 ft/s). The initial pressure drop is mainly decided by the filter class of the particle filter. A more efficient particle filter results in lower fouling rates but also in higher initial as well as operational pressure drop over the filter system. The filter efficiency should correspond to approximately F9 according to EN 779. The use of less efficient filter elements will increase the fouling rates.

● **5.6.2.3.2** The first-stage vane separator consists of vanes so that the inertial action of the droplet-laden air passing between them causes the droplets to be thrown out of the airstream onto the vanes. Droplets drain down the pockets of the vanes into a drain trough below.

The second-stage filter media shall be designed to have high-efficiency filter media to filter out large particles.

The third-stage filter media shall be designed to have high-efficiency filter media to filter out fine particles

If specified, an additional vane separator to remove droplets reentrained from upstream stages under conditions of high humidity will be provided.

5.6.2.3.3 If the additional vane separator is supplied, the drains are fed into a drain trap, which allows drainage without allowing the bypass of unfiltered air.

5.6.2.4 Low-velocity Inlet Filter System

5.6.2.4.1 A low-velocity inlet filter system usually consists of a droplet separator and several prefilter/filter stages. The object of the prefilter stage(s) is not only to protect the final fine filter stage and provide an acceptable life time of the final filter stage but also to improve the efficiency of the whole system.

5.6.2.4.2 The first-stage (noninertial) moisture droplet separator consists of alternate layers of flat and crimped stainless steel screen, held in a frame complete with drain holes.

5.6.2.4.3 The second-stage prefilter consists of high-performance, multilayered, noncellulose media enclosed in a stainless steel frame that remains rigid throughout the service life of the filter.

5.6.2.4.4 The third-stage final filter consists of ultra-high-efficiency fiberglass media formed into a mini-pleat configuration arranged into a totally rigid unit and sealed into a stainless steel enclosing frame.

5.6.2.5 Inlet Silencers

5.6.2.5.1 Silencer attenuation shall meet the noise limitations of 4.1.10.

5.6.2.5.2 Silencers shall be of welded stainless steel and shall be flanged.

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

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

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

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

5.6.2.5.7 Lifting provisions for handling shall be incorporated on the silencers.

5.6.2.6 Inlet Coolers

5.6.2.6.1 Evaporative Coolers

• **5.6.2.6.1.1** If specified as evaporative, the cooler shall be supplied complete with cooler media, circulation pump, sump drains, and corrosion resistant mist eliminator. The mist eliminator shall minimize moisture carryover into the inlet air stream at 105 % of maximum engine mass flow and worst case ambient conditions (low temperature and high humidity).

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

5.6.2.6.1.3 All evaporative cooler metallic housing and internal structural support shall be stainless steel. Manways shall be provided for complete access both upstream and downstream of the cooler media and mist eliminator sections. All piping shall be 300 series stainless steel.

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

5.6.2.6.1.5 The vendor shall specify the quality, pH, and quantity of water required to minimize cooler and water system operational problems.

5.6.2.6.1.6 The vendor shall advise the cooler efficiency and the pressure drop across the cooler system under maximum flow conditions.

5.6.2.6.2 Inlet Air Cooler Heat Exchanger

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

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

• **5.6.2.6.2.3** Purchaser shall specify the following coolant-side conditions in order for the vendor to properly size the exchanger and guarantee gas turbine performance:

a) maximum available flow,

b) maximum and minimum temperatures,

c) maximum and minimum pressures,

d) composition or analysis and cleanliness.

5.6.2.6.2.4 Based on this input, the vendor shall advise in the proposal the pressure drop across the cooler, the performance of the cooler in terms of inlet temperature reduction, as well as effect on turbine shaft output and fuel flow.

5.6.2.6.2.5 The vendor shall advise all controls being supplied with the cooling system as well as the controls and instrumentation required to be provided by the purchaser.

5.6.2.7 Inlet ducting

The inlet system shall include facilities or provisions for the manufacturer's recommended on-stream cleaning method per 5.6.1.16.

5.6.2.8 Inlet Expansion Joint

An acceptable inlet joint may be fabricated from a flexible material.

5.6.3 Exhaust Systems

5.6.3.1 Exhaust Silencer

5.6.3.1.1 Silencer attenuation shall meet the noise limitations of 4.1.10.

5.6.3.1.2 The basic material for construction of the exhaust silencer shall consider the minimum ambient temperature as well as the site rated exhaust temperature.

a) If the minimum site temperature is below the nil ductility temperature, a carbon steel capable of lower temperatures such as ASTM A516 shall be used.

b) If the site minimum ambient temperature is above the nil ductility temperature and the site rated exhaust temperature is below 455 °C (850 °F), AISI 1020 or equal shall be used.

c) If the site minimum ambient temperature is above the nil ductility temperature and the site rated exhaust temperature is above 455 °C (850 °F), a 400 series stainless steel, or equal shall be used. Additionally, for exhaust temperatures greater than 455 °C (850 °F) at site rated power, special precautions shall be exercised in the selection of silencer materials to avoid carburization or corrosion at these elevated temperatures.

5.6.3.1.3 Perforated plates or sheets shall be constructed of 300 or 400 series stainless steel except where a corrosive environment may produce stress corrosion cracking. If stress corrosion cracking is expected, the purchaser and vendor shall mutually agree on the materials of construction.

5.6.3.1.4 Acoustic and/or thermal insulation, whether externally or internally applied, shall be suitably captured to prevent its deterioration over time.

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

5.6.3.2 Exhaust Ducting

5.6.3.2.1 For exhaust temperatures greater than 455 °C (850 °F) at site rated power, special precautions shall be exercised in the selection of duct materials to avoid carburization or corrosion at these elevated temperatures.

5.6.3.2.2 If atmospheric relief devices and associated dampers are specified (see 5.6.1.6), caution shall be exercised regarding the degree of leakage to be tolerated and the location and routing of the atmospheric relief discharge.

• **5.6.3.2.3** If specified, emissions sampling ports shall be provided in the exhaust ducting (access ladder and platforms to be provided as necessary).

5.6.3.3 Exhaust Expansion Joint

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

5.7 Insulation, Weatherproofing, Fire Protection, and Acoustical Treatment

5.7.1 Insulation

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

NOTE ISO 13732:2006 explains the method for the assessment of responses to contact with surfaces.

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

NOTE Aeroderivative engines typically do not have external insulation applied.

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

5.7.2 Weatherproofing

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

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

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

5.7.3 Fire Protection

A fire protection system shall be furnished if any enclosure (including auxiliary enclosures) is specified by the purchaser or furnished by the vendor, unless specifically deleted from the vendor's scope of supply by the purchaser. The system shall consist as a minimum of the following:

a) a fire suppression system,

b) a fire detection system,

c) a gas detection system suitable for the detection of vapor/gas from the fuels system(s).

NOTE H_2S detectors may be required for gas turbines burning sour fuels.

• **5.7.3.1** The fire suppression system shall be designed in accordance with NFPA or ISO standards as specified. The purchaser will specify (see 5.7.3.1.1 and 5.7.3.1.2) any special design considerations to be included in the suppression system, including the specific fire suppression medium.

• **5.7.3.1.1** When NFPA standards have been specified in 5.7.3.1, the extinguishing system shall be selected from the following: NFPA 2001 (covers clean agent extinguishing systems), NFPA 750 (covers water mist systems) or NFPA 12 (covers carbon dioxide extinguishing systems).

• **5.7.3.1.2** When ISO standards have been specified in 5.7.3.1, the extinguishing system shall be selected from the following: ISO 14520 (covers clean agent extinguishing systems) or ISO 6183 (covers carbon dioxide extinguishing systems).

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

• **5.7.3.3** The fire detection system shall be designed in accordance with NFPA 72E or ISO 13387-7 as specified. Thermal detection shall be considered the minimum level of detection. Additional levels of detection, such as optical, may be specified by the purchaser.

• **5.7.3.4** The gas detection system shall be designed in accordance with NFPA 72E or IEC 61779-1 and 6 as specified.

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

5.7.4 Acoustical Treatment

5.7.4.1 If vendor furnished acoustical treatment is specified, the requirements of 4.1.10 shall apply.

● **5.7.4.2** Any special “far field” or neighborhood sound restrictions that are applicable shall be specified.

5.7.5 Enclosures

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

a) an enclosure surrounding the gas turbine and/or driven equipment;

b) an enclosure ventilation and purging system;

c) a fire protection system (see 5.7.3), including enclosure isolation devices.

5.7.5.2 Enclosures shall be weatherproof per 5.7.2.1 to 5.7.2.3.

5.7.5.3 Enclosures shall be designed to permit on-site maintenance. The degree of disassembly for maintenance shall be stated in the proposal. Enclosure floor compartment shall have drain connections and piping to facilitate removal of liquids.

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

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

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

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

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

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

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

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

● **5.7.5.6.3** Ventilation and purging flow shall enter and exit the enclosure via port(s). Each port shall be equipped with a back fire suppression damper and a minimum of one back flow damper within each supplied system. The purchaser will specify if additional ventilation ducting is required.

5.7.5.6.4 If cool down ventilation is required to prevent damage to the gas turbine, auxiliary systems, or instrumentation within the enclosure, unless otherwise specified, a UPS-powered fan shall be provided.

5.7.5.6.5 Ventilation system shall have been proved to ensure that no dead spaces exist within the enclosure either by physical type test or other means to avoid the chance of dangerous accumulations of vapor occurring.

5.8 Fuel System

5.8.1 General

5.8.1.1 Vendor Requirements

The vendor shall supply a complete system for receiving fuel from the purchaser's system. The fuel system shall be operable with the normal fuel or any alternative or starting fuels. The composition, range of heating values, temperatures, delivery pressures, and contaminant levels will be specified according to 5.8.2 and 5.8.4 in the inquiry specification. The vendor shall advise the purchaser of the effects of contaminants and corrosive agents on turbine operation. Refer to ISO 21789 for additional details on fuel systems.

5.8.1.2 Fuel Gas System

5.8.1.2.1 Components and Functionality

5.8.1.2.1.1 As a minimum, each gas fuel supply shall include the following functions:

a) manual isolation (see 5.8.1.2.2);

b) leak tight shut-off (see 5.8.1.2.4);

c) automatic fast acting shut-off (see 5.8.1.2.4);

d) flow control (see 5.8.1.2.3);

e) venting for depressurization between leak tight and automatic fast acting shut-off valves (see 5.8.1.2.4); and

f) venting for pipework depressurization (see 5.8.1.2.4 and 5.8.1.2.5).

5.8.1.2.1.2 Additional equipment shall be provided where a system risk assessment, of all reasonably foreseeable conditions and the reliability of the equipment used, indicates that additional control is required. Where the gas fuel supply system comprises more than one supply or a single supply is divided for multiple uses, equipment in each supply shall be duplicated such that the individual supplies comply with 5.8.1.2. A strainer shall be fitted in accordance with 5.8.1.2.6 where necessary for safe operation. Figure 10 shows the minimum arrangement and indicates the operation of the valves. Figure 11 and Figure 12 show typical alternative arrangements. Table 8 defines the symbols for Figures 10, 11, and 12.

NOTE National regulations may require certification of safety shut off valves and vent valves.

5.8.1.2.1.3 Additional equipment that shall be supplied includes but is not limited to:

a) manifold and nozzles;

b) necessary additional instrumentation;

● c) if the fuel gas pressure required by the vendor is higher then that available, a fuel gas compression system will be furnished by the vendor if specified by the purchaser;

● d) if specified, a fuel bypass valve and vent valve for purging the fuel gas line prior to light off shall be supplied;

e) a fuel gas pressure regulator, if required.

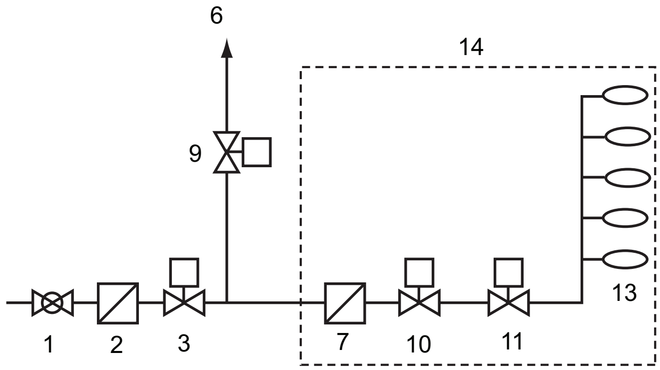


Figure 10—Fuel Gas System–Minimum Arrangement

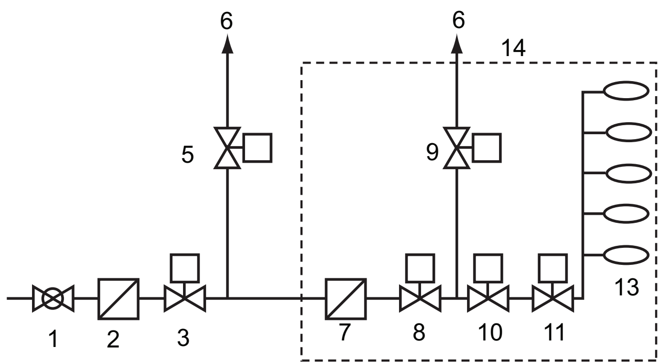


Figure 11—Fuel Gas System–Typical Alternative Arrangement

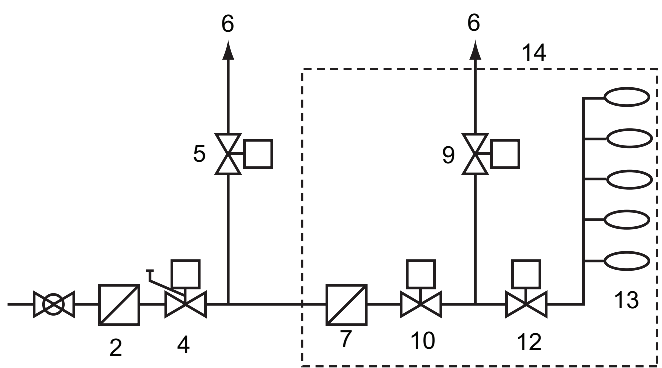


Figure 12—Fuel Gas System–Typical Alternative Arrangement

Table 8—Typical Gas Fuel System Components

Key	Type of Equipment
1	manual isolation valve
2	strainer, optional position
3	shut-off valve
4	shut-off valve and manual isolation valve
5	vent valve
6	vent to safe atmosphere
7	strainer, optional position
8	shut-off valve [a]
9	vent valve [b]
10	automatic fast acting shut-off valve [a]
11	flow control valve
12	flow control and shut-off valve [a]
13	combustion system
14	typical gas turbine enclosure or building limits

[a] Close on every shutdown.
[b] Vent on every shutdown.

5.8.1.2.1.4 Leak tight and automatic fast acting shut-off valves shall fail closed by permanent available energy, e.g. spring force. The fail-safe status of vent valves shall minimize any risks. All valves should be designed such that a tolerable level of risk and reliable operation will be achieved under all reasonably foreseeable operating conditions. Normally, automatic shut-off valves should not be energized to open until the associated downstream vent valve has been proved closed. Vent valves and associated pipework shall be sized to ensure the depressurized pipe remains at atmospheric pressure taking into account the potential for leakage in upstream valves. Integral valve combinations may be used providing the necessary functional safety is achieved without introducing additional risk.

5.8.1.2.2 Isolation

For operation during maintenance activity or by fire service personnel a valve, which shall be capable of manual operation, shall be fitted to the inlet of each gas turbine installation upstream of the automatic valves. This valve shall be identifiable, located in an accessible position and should be capable of being operated by an acceptable level of physical force.

NOTE Guidance on the physical strength for the hand-operation of equipment is given in EN 614-1:2006.

5.8.1.2.3 Flow Control Valve

The fuel flow control valve shall be designed and positioned to control the fuel flow to the gas turbine under all reasonably foreseeable operating conditions. Where failure of fuel flow control equipment may lead to excess fuel flow or other dangerous conditions, an additional independent device or devices shall ensure tolerable fuel flow to the gas turbine. Alternatively, the position of the control valve shall be monitored and if an “out of position to demand” is detected, a shutdown shall be initiated.

5.8.1.2.4 Shut-off Valves and Associated Vent Valve

Shut-off of the gas fuel supply shall be performed by two independently operated automatic shut-off valves; the piping between the valves shall be vented. At least one of the two shut-off valves shall be an automatic fast acting shut-off valve and one shall be a leak tight valve. Both valves shall be designed and positioned so that the fuel supply to the gas turbine will be shut-off in the event of a dangerous situation at a rate that will prevent dangerous failure of the gas turbine. One of the two shut-off valves may serve as the flow control valve. The flow control valve shall not be the automatic fast acting shut-off valve which shall be provided as an independent function. Upon shutdown, both shut-off valves (see Figure 10, Figure 11, and Figure 12—Item 3 and Item 10) shall be closed and the automatic vent valve opened (see Figure 10, Figure 11, and Figure 12—Item 9) to create atmospheric pressure in the supply line to eliminate the possibility of fuel entering the gas turbine in its shutdown condition. Where the design of the fuel system is such that the flow of fuel to the gas turbine requires further reduction, due to the stored energy in the piping system downstream of the automatic fast acting shut-off valve, an appropriately sized and positioned fast acting vent valve or alternative equipment shall be used to safely dissipate the stored energy.

5.8.1.2.5 Shut-off Valve—Outside the Gas Turbine Package

- A shut-off valve shall be located outside the gas turbine enclosure or building limits, or in a separately enclosed gas fuel package at the interface of the enclosure or building, to automatically isolate the fuel supply to the gas turbine in the event of a dangerous situation. If specified, the vendor shall provide this valve. The associated vent valve can be located either inside or outside the gas turbine or gas fuel package to vent the section of the pipe between the shut-off valve and the automatic fast acting shut-off valve. Where risk assessment indicates there is the potential for loss of containment from high-speed rotating equipment that could cause damage to the valves or rupture of the fuel supply pipe to the gas turbine, the shutoff valve(s) outside the gas turbine package and the supply pipe to the valves shall be located outside the zone where hazardous projectiles may occur from a potential failure of rotating equipment to ensure fuel shutoff can be achieved. Where the gas turbine package is located in a building, the risk assessment shall consider if the valves shall be located outside the building to provide additional isolation. The fuel shut-off and the vent valve(s) shall be operated automatically on a gas turbine trip if:

a) a fire has been detected within the gas turbine fire protection area; or

b) where risk assessment indicates that the cause of the trip may cause damage or failure of the pipe between the valves and the gas turbine package, or damage to the equipment on the gas turbine package, either leading to the uncontrolled leakage of fuel.

5.8.1.2.6 Strainer

5.8.1.2.6.1 General

A strainer shall be installed upstream of any automatic fast acting shut-off valve at a suitable location to prevent valve malfunction due to debris entering the valve.

● **5.8.1.2.6.2 Dual Strainers**

If specified, twin Y-type strainer(s) with a continuous flow transfer valve shall be supplied and mounted off-base and be capable of being cleaned while in operation. The transfer valve shall have a carbon steel body with a stainless steel internals suitable for the fuel gas composition.

5.8.1.2.6.3 Strainer Size

The strainer shall be sized to ensure the maximum size particle that will pass through will not damage downstream equipment, a nominal 5-μ element will normally suffice.

5.8.1.2.7 Valve Proving and Position Monitoring

At start-up the position of valves necessary for shutdown shall be confirmed. At shutdown, the correct function of the automatic fast acting shut-off valve, the automatic leak tight shut-off valve and the automatic vent valve shall be automatically monitored to ensure that correct operation of the valves has been achieved. The method used to monitor the correct function of the valves shall be determined by risk assessment. Where valve pressure proving is used additional equipment as appropriate may be installed to facilitate pressurization and pressure monitoring. Any additional valves shall be pressure proved as part of the proving sequence. The requirement to monitor the closed position of the vent valve shall be determined by risk assessment taking into account the location of the vent outlet and the hazardous area created should the vent valve fail to close.

5.8.1.2.8 Vent—Not to Atmosphere

Where, due to the toxicity of the gas or where adequate dispersion cannot be assured or where environmental considerations prohibit venting to atmosphere, the gas vents may be piped to a low-pressure flare stack < 50 kPa (7 psig), and additional precautions to prevent gas entering the gas turbine shall be implemented. As a minimum this shall consist of a double block and vent in the supply line prior to the gas turbine, the valves of which shall be proved and monitored for leak tightness. The vent valve shall be closed after venting to form a double block between the vent line and the gas turbine and the pressure in the vented section of the line monitored for any pressure increase. If an increase in pressure is detected, this shall be annunciated at the control system to enable rectification action to be taken. A purge connection shall be provided.

5.8.1.3 Fuel Gas Piping and System Requirements

5.8.1.3.1 Gas distribution piping and tubing shall be 316L stainless steel. Use of flexible hoses shall be minimized and, when used, limited to locations were relative movements must be accommodated. All fuel hoses must be made from 316L stainless steel, as a minimum, and covered with abrasion resistant braiding. System design must incorporate sufficient separation around each flexible hose at all times to prevent fretting damage to the braiding.

NOTE Sour gas at high temperatures may require duplex stainless steels.

5.8.1.3.2 Gas distribution piping downstream of the final filter shall be 316L stainless steel, full penetration butt-welded, and hydrotested.

5.8.1.3.3 The vendor shall state the maximum and minimum allowable fuel gas temperature supplied by the purchaser.

5.8.2 Gaseous Fuel

• 5.8.2.1 Composition

The purchaser will specify the composition of the gas (normal, alternate, or start-up) to be supplied. Composition of the gas should include analysis to hydrocarbons with 12 carbon atoms. Analysis should also include expected moisture (H_2O) content. Gas should be dry at the turbine fuel nozzles to prevent overtemperature damage to the turbine due to burning condensate. The vendor shall advise the purchaser if heating is required to maintain the gas above the dew point (see 5.8.2.7).

5.8.2.2 Contaminants

• **5.8.2.2.1** The contaminants likely to be found in fuel gas depend on the kind of gas involved, such as natural gas, coke oven gas, water gas, producer gas, and refinery gas. The concentration of contaminants in the gas will be specified on the datasheets by the purchaser. Some of the contaminants that are likely to be found include the following:

a) tar, carbon black, and coke;

b) water;

c) solids;

d) naphthalene and gas hydrates.

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

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

5.8.2.3 Corrosive Agents

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

5.8.2.3.2 Means shall be provided to prevent the emission of hazardous or toxic substances from the machine in accordance with ISO 14123-1:1998. If these measures cannot remove the hazard completely or reduce its effects to a nonhazardous level, then additional precautions shall be taken.

Such precautions may include the following among others:

a) increase height of vent to ensure adequate dispersion,

b) locate vent in an area which is not normally accessible to personnel,

c) monitor and alarm systems to be installed for hazardous atmosphere together with evacuation and shutdown processes.

5.8.2.4 Heating Value

• **5.8.2.4.1** The lower heating value of each gas will be specified. During operation, the actual heating value should not differ from the specified value by more than plus or minus 10 %.

• **5.8.2.4.2** For variations in heating value of more than 5 %, rate of change, together with upper and lower limits shall be specified by the purchaser because special equipment may be required for proper fuel control.

5.8.2.5 Fuel Supply Quality and Supply Conditions

5.8.2.5.1 Manufacturers shall provide detailed fuel specifications (including dew point margins for gaseous fuels and potential for wax formation) and condition ranges required for safe, reliable operation of their machines to the operator and to the designer of the fuel supply system. When the fuel does not comply with the detailed fuel specification the operator shall provide a fuel analysis (including up to C12 for gas fuels) so that the manufacturer can specify the specific fuel treatment necessary to mitigate any associated risks to a tolerable level. Treatment may include varying degrees of pressure and flow control, filtration, condensate removal, or heating of the fuel supply. The operator has the responsibility to ensure that the supplied fuel composition remains within the range of the agreed fuel specification throughout the lifetime of the plant, unless a deviation is formally agreed with the manufacturer.

5.8.2.5.2 Particular attention shall be given to the dew points and release of liquid hydrocarbons or water for gas fuels, and to wax formation at low temperatures for liquid fuels.

5.8.2.5.3 Attention should also be given to any trace element content likely to lead to an unacceptable reduction of metallurgical properties.

5.8.2.6 Pressure Testing

Where it is not practical to conduct a final assembly pneumatic or hydrostatic pressure test on the piping connected to the combustion system, a safe commissioning procedure shall be adopted to check for leaks on the running gas turbine. The procedure adopted shall be shown to achieve a tolerable level of risk and shall be appropriately documented.

5.8.2.7 Fuel Supply Heating

5.8.2.7.1 Electrically powered heaters or any alternative means shall be assessed for safety for use with the proposed fuel specification. Overheat protection shall be provided to ensure that excessive heat input to the fuel cannot occur.

5.8.2.7.2 Where heat exchangers use fluid media as the heat input, and fuel leakage followed by entrainment into the media can cause a dangerous situation, protective measures shall be taken. The potential for such leakage shall be minimized by detailed design.

5.8.2.7.3 Flame fired direct heating shall not be used. Where trace heating or comparable means are used, the design shall self-limit the temperature, or control thermostats shall be used.

5.8.3 Liquid Fuel System

5.8.3.1 Fuel control

5.8.3.1.1 As a minimum each liquid fuel supply shall include the following functions:

a) manual isolation (see 5.8.3.2),

b) flow control (see 5.8.3.3),

c) automatic fast acting shut-off (see 5.8.3.4),

d) leak tight shut-off (see 5.8.3.5),

e) spill and/or drain (see 5.8.3.4 and 5.8.3.6),

f) fuel pump.

5.8.3.1.2 Additional equipment shall be provided where a system risk assessment, of all reasonably foreseeable conditions and the reliability of the equipment used, indicates that additional control is required. Different arrangements and combinations of devices may be utilized to fulfill the above functions provided the concepts described in 5.8.3 are achieved and the fuel is shut-off at a rate which will prevent dangerous failure of the gas turbine and the possibility of fuel entering the gas turbine in its shutdown condition is eliminated. Figure 13 shows a typical arrangement. Other arrangements or configurations are permitted. Shut-off valves shall fail closed by permanent available energy, e.g., spring force. The fail-safe status of drain valves shall minimize any risks. All valves should be designed such that a tolerable level of risk and reliable operation will be achieved under all reasonably foreseeable operating conditions.

5.8.3.2 Isolation

For operation during maintenance activity or by fire service personnel a valve, which shall be capable of manual operation, shall be fitted to the inlet of each gas turbine installation upstream of the automatic valves. This valve shall be clearly marked, located in an accessible position and should be capable of being operated by an acceptable level of physical force.

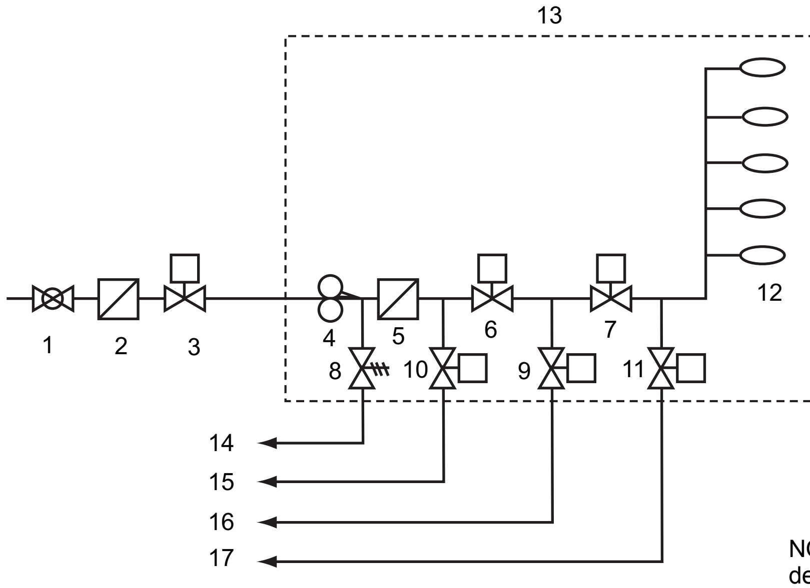
NOTE Guidance on the physical strength for the hand-operation of equipment is given in EN 614-1:2006.

5.8.3.3 Flow Control Device

The fuel flow control device shall be designed, located and governed to control the fuel flow to the gas turbine under all reasonably foreseeable operating conditions. Where failure of fuel flow control equipment may lead to excess fuel flow or other dangerous conditions, an additional independent device or devices shall ensure tolerable fuel flow to the gas turbine. Alternatively the position of the control valve shall be monitored and if an “out of position to demand” is detected, a shutdown shall be initiated.

5.8.3.4 Automatic Fast Acting Shut-off Valve and Spill Valve

Shut-off of the liquid fuel supply shall be performed by two independently operated automatic shut-off devices. At least one valve shall be an automatic fast acting shut-off valve. After operation of the shut-off devices and after any fuel purging, a valve shall drain a section of the supply line to eliminate the possibility of fuel entering the gas turbine in its shutdown condition. This valve shall be sized to ensure the drained pipe volume remains near atmospheric



NOTE See Table 9 for the definition of the symbols.

Figure 13—Typical Liquid Fuel System Arrangement

Table 9—Typical Liquid Fuel System Components

Key	Type of Equipment
1	manual isolation valve
2	filter or strainer, optional position
3	shut-off valve
4	fuel pump, may be located outside gas turbine enclosure
5	filter of strainer, optional position
6	flow control device
7	automatic fast acting shut-off valve [a]
8	relief valve
9	spill valve
10	spill valve—alternative location
11	drain valve [b]
12	combustion system
13	typical gas turbine enclosure or building limits
14	relief
15	return to supply—alternate location with 10
16	return to supply
17	drain

[a] Close on every shutdown.

[b] Controlled operation on shutdown.

pressure taking into account the potential for leakage in upstream valves. Where a spill valve does not spill to atmospheric pressure, a drain valve shall be supplied in accordance with 5.8.3.6. Operational requirements may require the liquid fuel system to remain pressurized when liquid fuel is not being furnished to the engine in order to minimize either starting time or fuel transfer. In these situations, any necessary design steps and risk assessment shall validate that this results in a tolerable level of risk. Where spill flow is returned to the pump suction sufficient cooling and/or make up flow shall exist to prevent overheating and the potential for vapor lock, or the fuel supply temperature before the pump suction should be monitored and a shutdown initiated if overheating occurs.

5.8.3.5 Leak Tight Shut-off Valve—Outside the Gas Turbine Package

An automatic shut-off valve shall be located outside the gas turbine package to automatically isolate the fuel supply to the gas turbine in the event of a dangerous situation (see Figure 13—Item 3). Where risk assessment indicates there is the potential for loss of containment from high-speed rotating equipment that could cause damage to the valves or rupture of the fuel supply pipe to the gas turbine, the shut off valve(s) outside the gas turbine package and the supply pipe to the valves shall be located outside the zone where hazardous projectiles may occur from a potential failure of rotating equipment to ensure fuel shutoff can be achieved. Where the gas turbine package is located in a building the risk assessment shall consider if the valve shall be located outside the building to provide additional isolation.

The valve shall be operated automatically on a gas turbine trip if:

a) a fire has been detected within the gas turbine fire protection area; or

b) where risk assessment indicates that the cause of the trip may cause damage or failure of the pipe between the valves and the gas turbine package, or damage to the equipment on the gas turbine package, either leading to the uncontrolled leakage of fuel.

5.8.3.6 Drain Valve

Where required to achieve a tolerable level of risk during shutdown and where the spill valve does not spill to atmospheric pressure, an automatic drain valve shall be installed to drain fuel downstream of the automatic fast acting shut-off valve which shall operate on every shutdown to drain liquid. The valve may be closed during periods of shutdown where other risks are mitigated. Where a drain valve is used to drain a part of the system which on shutdown will be subject to the reverse flow of high pressure and temperature gas turbine compressor delivery air capable of causing the ignition of any hydrocarbons in the drain or purge lines, the drain sequence shall be controlled to prevent this condition. Alternatively cooling and/or a flame arrester shall be used to prevent any ignition escalating outside the gas turbine package or a separator mechanism shall be used to vent any hot gases to atmosphere while draining fluids to a waste liquids tank. If there is the potential for reverse flow from the tank, appropriate devices and/or instrumentation shall be installed so that protection is provided against reverse flow into the gas turbine under all reasonably foreseeable conditions.

5.8.3.7 Filter/Strainer

A filter/strainer shall be fitted upstream of the fuel flow control device and automatic fast acting shut-off valve at a suitable location to prevent device or valve malfunction due to debris entering the device or valve. Duplex fuel filters shall be used with a continuous flow transfer valve if liquid is the primary fuel. A single filter may be supplied if the liquid fuel is not the primary fuel. When provided, duplex fuel filters shall be accessible with the idle filter capable of being cleaned while in operation. The transfer valve shall have a carbon steel or stainless steel body with stainless steel internals.

5.8.3.8 Valve Proving and Position Monitoring

At start-up the position of valves necessary for shutdown shall be confirmed. At shutdown the correct function of the automatic fast acting shut-off valve, the automatic leak tight shut-off valve and the automatic drain valve shall be monitored to ensure that correct operation of the valves has been achieved. The method used to monitor the correct function of the valves shall be the subject of risk assessment. The requirement to monitor the position of the drain valve, where supplied, shall be the subject of risk assessment taking into account the location of the drain outlet and the hazard that may be created should the valve malfunction.

5.8.3.9 Thermal Relief

Where the potential exists for a liquid to be trapped between closed leak tight valves, a suitably located thermal relief shall be provided.

5.8.3.10 Multi-fuel Systems

It shall not be possible under any condition for the reverse flow of fuel to occur into any other system where this may lead to danger. Where this may occur, additional safety devices shall be fitted to prevent reverse flow. Appropriate precautions shall be taken to ensure that liquid fuels cannot enter the gas fuel system where gas fuel is used to purge the liquid fuel burners. Where only a single fuel can be fired at any one time, interlocks shall be provided to ensure that the standby fuel system cannot operate or is isolated. Where more than one fuel can be fired at any one time, it shall be assured that excess energy input due to overfuelling cannot occur in the gas turbine.

5.8.3.11 Fuel Purging

Where forward and reverse purge/drain sequences are used during start-up, operation, or shutdown, risk assessment shall be carried out taking into account all reasonably foreseeable risks including but not limited to:

a) failure of reverse purge sequence during shutdown which may leave low auto-ignition temperature fuels in the feed lines with the potential for uncontrolled ignition on a restart;

b) inadequate draining of liquid fuel after a false start which may leave liquid fuel in the drain lines with the potential for uncontrolled ignition on restart;

c) uncontrolled shutdown whilst running on low auto-ignition temperature fuel causing purge sequences to fail;

d) the potential for ignition of vapors in the purge drain lines/vent tank(s) due to the temperature of reverse purge combustion air;

e) contamination of liquid fuel storage with alternative low auto-ignition fuels should a purge/drain sequence fail with the potential for uncontrolled ignition on restart due to contamination of the fuel used for starting;

f) the potential for vapor lock (change of state resulting in increased volume and pressure);

g) uncontrolled supply, venting or draining of dangerous media;

h) the presence of condensates at low points.

Risk mitigation measures such as the use of appropriate instrumentation, double block and vent valves, valve position monitoring, prevention of reverse flow, separation of media, flame arresters etc., shall be considered.

5.8.3.12 Fuel Drainage

Where liquid fuel is used suitable drain points shall be incorporated to drain off unburnt fuel from the pressure section of the casing and/or exhaust system (e.g., in the event of a flame failure on start-up). The drain points shall have valves preferably automatically operated which open on shutdown and close as part of the start sequence. If manual valves are used clear instructions shall be given on their operation. The start cycle shall provide a sufficient period to allow draining of this un-burnt fuel prior to initiating a restart by the use of automatic drain valves. Automatic or manual operation of the valves as well as their operating schedule, their fail safe position, the monitoring of the effectiveness of the drain or of the valve position and the requirement of a prestart purge shall be determined on the basis of risk assessment, taking into account the risk of uncontrollable overspeed caused by burning undrained fuel during start-up, hot gas entering the drain system during operation and unburnt gaseous fuel and air mixtures entering the drain system.

5.8.3.13 Other equipment that may be supplied to ensure a fully functional system includes:

a) atomizing air (source to be mutually agreed upon);

b) necessary instrumentation;

c) flow dividers (if required by the vendor);

d) fuel nozzles and manifold.

5.8.3.14 If heating of the fuel is required to vaporize and superheat the fuel, or to lower the viscosity to within the manufacturer's limits, heating equipment will be furnished by the purchaser. Heater requirements shall be in accordance with 5.8.2.7.

● **5.8.3.15** If specified, fuel transfer equipment shall be supplied.

5.8.4 Liquid Fuel

5.8.4.1 Classification

Fuel classifications for gas turbines are listed in ASTM D2880 and ASTM D1655.

a) ASTM D2880 divides fuel oils into five grades based on their applicability for use in gas turbines. It does not include fuels primarily intended for jet aircraft use.

b) ASTM D1655 covers fuels primarily intended for use in jet aircraft. Three types are provided and are differentiated by their flash points, boiling ranges, and freezing points.

5.8.4.2 Properties

Both ASTM D2880 and ASTM D1655 place limiting values on a number of the properties of the oils in each grade. The properties selected for limitation are those believed to be of the greatest significance in determining performance characteristics of the oils in various gas turbine applications. Other property considerations include the following.

a) In some instances, mutual agreement on permissible contaminant levels in the fuels to be burned in the gas turbine is required between the interested parties.

   NOTE See ASTM D2880, Section 1.1, for additional details.

b) For those cases in which no mutual agreement is reached, the contaminant levels defined as permissible by the gas turbine manufacturer's fuel specification shall apply.

c) Gas turbine operation and maintenance requirements are benefited if fuels have thermal stability, good combustion quality, and low sulfur and ash content. These qualities become increasingly important when the temperatures of the fuel system and operating turbine are high or when long periods between overhaul are desired.

● **5.8.4.3 Grades or Types**

5.8.4.3.1 The Purchase shall specify which grades of ASTM D2880 shall be used, as follows.

a) Grade 0-GT includes naphtha, Jet B, and other light hydrocarbon liquids that characteristically have low flash points and low viscosities compared to those of kerosene and fuel oils.

b) Grade 1-GT is a light distillate fuel suitable for use in nearly all gas turbines.

c) Grade 2-GT is a distillate that is heavier than Grade 1-GT, and it can be used by gas turbines not requiring the clean burning characteristics of Grade 1-GT. Fuel heating equipment may be required by the gas turbine depending on the fuel system design or the ambient temperature conditions or both.

d) Grade 3-GT may be a distillate that is heavier than Grade 2-GT, a residual fuel oil that meets the low ash requirement, or a blend of a distillate and a residual fuel oil. If Grade 3-GT is specified, the gas turbine will require fuel heating in almost every installation.

e) Grade 4-GT includes most residuals and some topped crude oils. Because of the wide variation and lack of control of properties, the gas turbine manufacturer should be consulted about acceptable limits on properties.

● **5.8.4.3.2** The Purchaser shall specify which grades of ASTM D1655 shall be used, as follows.

a) Jet A and Jet A-1 are relatively high flash point distillates of the kerosene type. They represent two grades of kerosene fuel that differ only in freezing point.

b) Jet B is a relatively wide boiling range volatile distillate.

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

5.8.5 Dual Fuel Operation

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

5.8.5.2 The dual fuel system shall provide smooth, bidirectional fuel transfer without shutdown or interruption of load-carrying ability.

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

5.8.6 Effect of Fuel Type

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

5.8.7 Emission Suppression Systems

● **5.8.7.1** If specified, the gas turbine shall be provided with the necessary equipment for emission suppression for gas-fueled or liquid-fueled units. The vendor shall fully describe the proposed system, including the following performance information associated with the emission suppression system:

a) emission variations with all fuels being used;

b) effect of ambient temperature range on emissions;

c) effect of anti-icing system on emissions, if supplied;

d) associated engine power and engine heat rate.

• **5.8.7.2** The purchaser shall specify the site-specific requirements for:

a) emissions levels;

b) power output load range for which these emission level are acceptable;

c) type of emission suppression system required (wet or dry);

d) complete fuel analyses to be used per 5.8.1.1.

NOTE Emission refers to contaminants in the exhaust stream such as:

1) NO_X (oxides of nitrogen);

2) CO (carbon monoxide);

3) UHC (unburned hydrocarbons);

4) others (sulfur, particulate, etc.).

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

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

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

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

5.8.8 Ignition Systems

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

5.9 Special Tools

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

6 Inspection, Testing, and Preparation for Shipment

6.1 General

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

• **6.1.2** If specified, the purchaser's representative, the vendor's representative, or both shall indicate compliance in accordance with accepted inspection documents by initialing, dating, and submitting a checklist to the purchaser before shipment.

6.1.3 After advance notification by the vendor to the purchaser, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing, or inspection of his equipment is in progress. In the proposal, the vendor shall advise the purchaser which equipment can be inspected on a typical basis only.

6.1.4 The vendor shall notify sub-vendors of the purchaser's and vendor's inspection and testing requirements.

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

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

6.1.5.2 If a preliminary test is performed prior to a witnessed test, the vendor shall notify the purchaser in writing (email) of the details of the successful test completion.

NOTE Due to the complex testing requirements, it is recommended the purchaser's representative be present during setup.

6.1.5.3 Since the timing of observed tests is not exact, the purchaser's representative should expect to be in the factory longer than for a witnessed test.

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

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

6.2 Inspection

6.2.1 General

6.2.1.1 The vendor shall keep the following data available for at least 20 years for examination or reproduction by the purchaser or his representative upon request:

a) necessary certification of material, such as mill test reports;

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

c) results of documented tests and inspections, including fully identified records of all heat treatment and radiography;

• d) if specified, final-assembly maintenance and running clearances.

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

● **6.2.1.3** In addition to the requirements of 4.10.4.1 and the ASTM material specification, the purchaser shall specify:

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

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

6.2.2 Material Examination

6.2.2.1 General

6.2.2.1.1 Equivalent international standards can be accepted by the purchaser for individual tests in 6.2.2.1.1 to 6.2.3.4. Vendor shall indicate all specifications used.

● **6.2.2.1.2** When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required (see 4.10.4.1 and 6.2.1.3), the recommended practices in 6.2.2.2 through 6.2.2.5 shall apply unless other procedures are specified by the purchaser and agreed to by the vendor. Cast iron may be inspected in accordance with 6.2.2.4 and 6.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 6.2.2.2 through 6.2.2.5. The material inspection of pressure-containing parts is covered in 4.10.4.6.

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

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

6.2.2.2 Radiography

Radiography shall be based upon the procedures of ASTM E94 or other internationally recognized standards approved by the purchaser. Vendor shall indicate all specifications used.

6.2.2.3 Ultrasonic Inspection

Ultrasonic inspection shall be based upon the procedures of ASTM A609 (castings), ASTM A388 (forging), or ASTM A578 (plate), or other internationally recognized standards approved by the purchaser. Vendor shall indicate all specifications used.

6.2.2.4 Magnetic Particle Inspection

Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709 or other internationally recognized standards approved by the purchaser. Vendor shall indicate all specifications used.

6.2.2.5 Liquid Penetrant Inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E165 or other internationally recognized standards approved by the purchaser. Vendor shall indicate all specifications used.

6.2.3 Mechanical Inspection

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

6.2.3.2 All oil systems furnished shall meet the cleanliness requirements of API 614, ISO 10438, or other internationally recognized standards approved by the purchaser. Vendor shall indicate all specifications used.

• **6.2.3.3** If specified, the equipment and all piping and appurtenances shall be inspected before heads are welded onto vessels, openings in vessels or exchangers are closed, or piping is finally assembled.

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

6.3 Testing

6.3.1 General

6.3.1.1 Equipment shall be tested in accordance with 6.3.2 and 6.3.4. Other tests that may be specified by the purchaser are described in 6.3.3 and 6.3.5 to 6.3.6. Equivalent international standards can be accepted by the purchaser for individual tests. Vendor shall indicate all test specifications used.

6.3.1.2 At least six weeks before the first scheduled test, the vendor shall submit to the purchaser, for his review and comment, detailed procedures for all tests, which include the mechanical running test and all specified purchaser tests (see 6.3.5), as well as acceptance criteria for all monitored parameters.

6.3.1.3 Notification requirements are covered in 6.1.1. However, the vendor 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 vendor shall notify the purchaser not less than five working days before the new test date unless otherwise mutually agreed.

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

6.3.2 Hydrostatic Test

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

6.3.2.2 Pressure-containing parts as identified in 6.3.2.1, piping and auxiliaries, shall be tested hydrostatically with liquid at a minimum of one and a half times the maximum allowable working pressure. The minimum hydrotest pressure shall not be less than 1.5 bar (20 psi). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. The hydrostatic testing of nonpressure retaining parts (such as an atmospheric oil tank) shall be mutually agreed between the vendor and the purchaser.

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

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

6.3.2.3 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that of the operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or in Section VIII, Division 1 of the ASME Code for vessels, or other internationally recognized standards approved by the purchaser. Vendor shall indicate all test specifications used. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The datasheets shall list actual hydrostatic test pressures.

6.3.2.4 Where applicable, tests shall be in accordance with the code or standard to which the part has been designed. In the event that a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

• **6.3.3 Pneumatic Testing**

If specified, in addition to hydrostatic testing of pipe systems the manufacturer shall also perform, complete or partial system, pneumatic tests of the gas fuel system using air or other gases at the system design pressure. This test shall be performed after completion of the hydrostatic test (see 6.3.2).

6.3.4 Mechanical Running Test

6.3.4.1 This test may be run at a no-load condition. The purpose of the test is to confirm the mechanical integrity and verify that the vibration acceptance criteria of the equipment are met. The requirements of 6.3.4.1.1 through 6.3.4.1.12 shall be met before the mechanical running test is performed.

NOTE This test can be combined with the performance test (see 6.3.5.1) for a full load mechanical running test.

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

6.3.4.1.2 All oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the manufacturer's operating instructions for the specific unit being tested. During the test, the gas turbine shall run for 60 minutes at the maximum allowable lube oil temperature. For pressure lubricating systems, oil flow rates for each bearing housing through the entire operational speed range of gas turbine train shall be measured.

6.3.4.1.2.1 It may be permissible to use different oil viscosity for the factory test, if the site has either an exceptionally high or low ambient temperature.

6.3.4.1.2.2 Some gas turbines use two different types of lube oil. When synthetic oil is used in operation, the same oil shall be used for shop testing. Substitution of different test oil shall be done by mutual consent only.

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

6.3.4.1.4 All warning, protective, and control devices used during the test shall be checked and adjusted as required.

6.3.4.1.5 Testing with the contract coupling or couplings is preferred. If this is not possible, mass shall be added to the shaft end or ends, using moment simulators or test couplings, in accordance with ISO 10441 (API 671) such that the effective overhanging moment is within 10 % of the effective moment with the contract coupling.

• **6.3.4.1.6** If specified, auxiliary systems mounted on the gas turbine main base shall be tested with the gas turbine during the mechanical run. These auxiliary systems may include but are not limited to the job oil system(s), fuel systems, starting and cool-down drive systems, atomizing liquid fuel system, and auxiliary gear box. The purchaser shall specify which systems shall be included in the test.

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

NOTE The inlet system, de-icing systems, exhaust system, sound enclosure, and fire protection system are generally not tested during the mechanical run. They may be included in the complete package operation test (see 6.3.5.2.1).

6.3.4.1.8 Test stand oil filtration shall not exceed 10 µm nominal. Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10443 (API 614) before any test is started.

6.3.4.1.9 All purchased vibration probes, cables, oscillator-demodulators, and accelerometers shall be in use during the test. If vibration probes are not furnished by the equipment vendor or if the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API 670 shall be used. During the test, Bode, polar, Fast Fourier Transform, and cascade plots shall be made representing the behavior during start and shutdown transients and under steady conditions. The frequency range of the plots shall include antifriction bearings and vane/blade excitation ranges.

6.3.4.1.10 Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting revolutions per minute, peak-to-peak shaft displacement or casing velocity and phase angle. Presentation of vibration displacement and phase marker shall also be by oscilloscope.

6.3.4.1.11 The vibration characteristics determined by the use of the instrumentation specified in 6.3.4.1.9 and 6.3.4.1.10 shall serve as the basis for acceptance or rejection of the machine (see 4.7.5.2).

6.3.4.1.12 If the vendor installs vibration probes, in addition to that required by 6.3.4.1.9 for the test, the vibration data (minimum and maximum values) shall be recorded and the probe angle and shaft location shall be documented.

6.3.4.2 Unless otherwise specified, the mechanical running test of the equipment shall be conducted as specified in 6.3.4.2.1 through 6.3.4.2.5.

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

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

6.3.4.2.2 The output speed shall be increased to maximum allowable speed and the equipment shall be run for a maximum of 15 minutes at maximum allowable speed (see 3.22).

6.3.4.2.3 Overspeed trip devices shall be checked and adjusted until values within 1 % of the minimal trip setting are attained. For electronically controlled overspeed trip devices, speeds above 100 % may be simulated. Mechanical overspeed devices, if included, shall attain three consecutive nontrending trip values.

6.3.4.2.4 If utilized for the test, the speed governor and any other speed regulating devices shall be tested for smooth performance over the operating speed range. No-load stability and response to the control signal shall be checked. As a minimum, the following data shall be recorded for governors: sensitivity and linearity of relationship between speed and control signal and, for adjustable governors, response to the control signal shall be checked.

6.3.4.2.5 The speed of the driven shaft shall be adjusted to the maximum continuous speed, and the equipment shall be run for 4 hours, unless otherwise agreed.

6.3.4.3 The requirements of 6.3.4.3.1 through 6.3.4.3.5 shall be met during the mechanical running test.

6.3.4.3.1 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 shall not exceed the limits of 4.7.5.2 and shall be recorded throughout the operating speed range.

6.3.4.3.2 While the equipment is operating at maximum continuous speed and at other speeds that may have been specified in the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous. As a minimum, these sweeps shall cover a frequency range from 0.05 to 6 times the maximum continuous speed. As a minimum, a frequency sensitivity range of 0.05 to 6 times the maximum continuous speed should be used. If rolling element bearings are utilized in the train, the upper end of the frequency range shall be adjusted to include two times the rolling element passing frequency, for applicable sensors placed near the subject bearings. Similarly, if gearboxes are present, the range shall be adjusted to include the gear tooth passing frequency for the relevant sensors. If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 4.7.5.2., the purchaser and the vendor shall mutually agree on requirements for further investigation which may include additional testing to determine the acceptability of the equipment.

6.3.4.3.3 For a prototype or modified gas turbine model, the mechanical running test shall verify that lateral critical speeds conform to the requirements of 4.7.2. Any noncritically damped critical speed below the trip speed shall be determined during the mechanical running test and stamped on the nameplate followed by the word “test”. For flexible-shaft machines, the first lateral critical speeds shall be determined during the mechanical running test.

• **6.3.4.3.4** Synchronous vibration amplitude and phase angle vs speed for deceleration shall be plotted before and after the 4-hour run. Both the filtered (one per revolution) and the unfiltered vibration magnitudes shall also be plotted. If specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be 400 revolutions per minute to the specified driver trip speed.

6.3.4.3.5 For a prototype or modified gas turbine model, shop verification of the unbalanced response analysis shall be performed in accordance with 4.7.2.15.

6.3.4.3.6 Real-time vibration data (see Annex B—Item 32) as agreed by the purchaser and vendor shall be recorded and a copy provided to the purchaser. The vendor shall identify the software required to read the vibration data.

NOTE Some vendors utilize data acquisition software that is not commercially available.

6.3.4.4 Unless otherwise specified, the requirement of 6.3.4.4.1 through 6.3.4.4.2 shall be met after the mechanical running test is completed.

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

• **6.3.4.4.2** If specified, spare rotors shall also be given a mechanical running test in accordance with the requirements of this standard.

• 6.3.5 Optional Shop Tests

If specified, the shop tests described in 6.3.5.1 through 6.3.5.14 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

• 6.3.5.1 Performance Test

If specified, the machine shall be tested in accordance with ASME Performance Test Codes 1 and 22, or ISO 2314, as specified by the purchaser. Vibration shall be measured and recorded during this test as specified in 6.3.4.1.10 and 6.3.4.1.12.

6.3.5.2 Complete Unit Test

If specified, such driven components as compressors, gears, generators, helper drivers and auxiliaries that make up a complete unit shall be tested together during the (no-load) mechanical running test. The complete unit test shall be performed in place of or in addition to separate tests of individual components specified by the purchaser.

NOTE This test can also be combined with the performance test (see 6.3.5.1) for a full load string test.

● **6.3.5.2.1 Package Test**

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

a) control panel,

b) auxiliary gear,

c) starting equipment,

d) lube-oil system,

e) hydraulic oil system,

f) gas fuel system,

g) liquid fuel system,

h) atomizing air system,

i) inlet system,

j) exhaust system,

k) enclosure with the associated equipment,

l) fire protection,

m) de-icing.

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

● **6.3.5.2.2** If specified, torsional vibration measurements shall be made to verify the vendor's analysis.

● **6.3.5.3 Gear Test**

If specified, the gear shall be tested with the gas turbine unit during the mechanical running test.

NOTE Load gears that have their own radial and thrust bearings are usually tested separately at the gear manufacturer's factory.

● **6.3.5.4 Sound-level Test**

If specified, the sound-level test shall be performed in accordance with ISO 3744 or other agreed standards.

● **6.3.5.5 Rotor Overspeed Test**

If specified, the vendor shall perform an overspeed test of the rotor at 120 % of rated speed for 2 minutes to demonstrate the mechanical integrity and vibration behavior of the rotor.

• **6.3.5.6 Auxiliary-equipment Test**

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

• **6.3.5.7 Ventilation System Validation**

If specified, the ventilation system shall be tested to demonstrate the safe running of the machine and proof that dilution ventilation will meet the safety requirements and design intent (see ISO 21789). The vendor shall indicate all specifications used.

• **6.3.5.8 Enclosure Leak Test**

If specified, the fire protection system shall be tested to prove the retention capability of the extinguishing medium.

• **6.3.5.9 Post-test Inspection**

The gas turbine shall be inspected after satisfactory completion of the mechanical running test. An inspection of the gas turbine internals by boroscope, visually via the inlet and exhaust connections and other access means available shall be performed to document the condition after the running test and documentation shall be provided to the purchaser. If the mechanical running test is unsatisfactory, dismantling, inspection, and reassembling to identify the reason for and to correct the failure shall be performed.

• **6.3.5.10 Inspection of Hub/Shaft Fit for Hydraulically Mounted Couplings**

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

• **6.3.5.11 Governor Response and Emergency Overspeed Trip Systems Tests**

6.3.5.11.1 The response time of the speed governing systems shall be continuously recorded to confirm compliance with the maximum speed rise requirements of 5.4.3.5 and the NEMA class of the specified governor (see 5.4.1.7).

6.3.5.11.2 The response time of the emergency overspeed trip systems shall be recorded to confirm compliance with 5.4.4.2 b) and the NEMA class of the specified governor (see 5.4.1.7).

• **6.3.5.12 Spare Parts Test**

If specified, spare parts, such as couplings, gears, bearings, and seals, shall be tested to the same standards as the original parts.

• **6.3.5.13 Fire Protection Tests**

The fire protection systems tests shall confirm compliance with NFPA or ISO standards as specified in 5.7.3.1.

• **6.3.5.14 Other Tests and Inspections**

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

• **6.3.6 Field Test**

If specified, a field performance test shall be performed to determine the gas turbine's efficiency and power at site. This test shall be in accordance with ISO 2314 or PTC 22. The vendor shall indicate all test specifications used.

NOTE The Gas Machinery Research Council *Gas Turbine and Compressor Field Testing Guidelines*, Release 2.0, or other equivalent standards can also be used.

6.4 Preparation for Shipment

• **6.4.1** The gas turbine units shall be suitably prepared for the type of shipment specified, including blocking of the rotors when necessary. Blocked rotors shall be identified by corrosion resistant tags externally attached with stainless steel wire. The preparation shall make the equipment suitable for six months of outdoor storage (under the conditions specified in 4.1.19) from the time of shipment, with no disassembly required before operation except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser shall consult with the vendor regarding the recommended procedures to be followed. Any gas turbine component accessory, or instrument not suitable for the extremes of temperature that can be expected during shipment or storage, shall be identified by the vendor in the proposal.

6.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, as described API 686, Chapter 3. The vendor shall provide a detailed packing list for all individual shipments in advance to permit the purchaser to plan site preparation and storage. Aeroderivative gas generators shall be preserved in accordance with the manufacturer's instructions and shipped in the manufacturer's approved packing.

NOTE Aeroderivative turbine gas generators are commonly shipped separately from the gas turbine package.

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

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

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

6.4.3.3 The interior of the equipment shall be clean, free from scale, welding spatter and foreign objects; and sprayed or flushed with a rust preventive. The rust preventive shall be applied through all openings while the rotor is rotated.

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

6.4.3.5 Flanged openings shall be provided with metal closures at least 5 mm ($^{3}/_{16}$ in.) thick with elastomer gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures. Threaded openings shall be sealed with steel caps or solid-shank steel plugs. In no case shall nonmetallic (such as plastic) plugs or caps be used. Each opening shall be sealed so that the protective cover cannot be removed without the seal being broken.

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

NOTE These are shipping plugs; permanent plugs are covered in 4.4.4.

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

6.4.3.8 Lifting points and the center of gravity shall be clearly identified on the equipment package. The recommended lifting arrangement shall be in the installation manual.

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

• **6.4.3.10** When a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least three years. The rotor shall be treated with a rust preventative and shall be housed in a vapor-barrier envelope with a low-release volatile-corrosion inhibitor. The rotor shall be crated for domestic or export shipment, as specified. A purchaser-approved resilient material 3.0 mm (1/8 in.) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)] shall be used between the rotor and the crude at the support areas. The rotor shall not be supported at journals.

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

6.4.4 Components (both individual pieces and packages sets) shipped with mounted, preassembled piping, tubing or wiring shall comply with the requirements of legal or national safety regulations as dictated by location.

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

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

6.4.7 At least one paper and one electronic copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

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

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

7 Vendor's Data

7.1 General

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

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

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

b) the job/project number;

c) the equipment service name and item number;

d) the inquiry or purchase order number;

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

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

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

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

b) datasheets;

c) applicable specifications and previously agreed upon exceptions;

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

e) quality assurance program and procedures;

f) inspection, expediting, and testing;

g) schematics and bills of material (BOM) of auxiliary systems;

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

i) coupling selections;

j) thrust bearing sizing and estimated loading;

k) rotordynamic analysis;

l) other technical items.

7.2 Proposals

7.2.1 General

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

7.2.2 Drawings

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

a) A general arrangement or outline drawing for each major skid or system, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and maximum maintenance weights (indicated for each piece). The direction of rotation and the size and location of major purchaser connections shall also be indicated.

NOTE Typical drawings may be used.

b) Cross-sectional drawings showing details of the gas turbine proposed.

c) Schematics of all auxiliary systems, such as fuel, lube oil, water/steam injection, control, and electrical systems. BOM shall be included.

d) Methods of lifting the assembled machine or machines and major components. [This information may be included on the drawings specified in Item a) above.]

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

7.2.3 Technical Data

All the technical data shall be given in units of measurement according to the purchase order (SI or USC). If needed, the technical data in alternate units can be included in parentheses. The following technical data shall be included.

a) Purchaser's datasheets with complete vendor's information entered thereon and literature that fully describes the details of the offering.

b) Purchaser's noise datasheet.

c) VDDR (see Annex B) indicating the schedule according to which the vendor agrees to transmit all the data specified as a part of the contract.

d) Schedule for the shipment of the equipment, in weeks after receipt of the order.

e) List of the major wearing components showing interchangeability with other purchaser units.

f) List of spare parts recommended for start-up and normal maintenance purpose.

g) List of special tools furnished for maintenance. Any metric items included in the offering shall be identified.

h) Statement of any special weather protection and winterization required for startup, operation, and periods of idleness under the various site conditions specified (see 4.1.19). The statement shall show the protection to be furnished by the purchaser, as well as the protection that is included in the vendor's scope of supply.

i) A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas, and lube oil, including the quantity of lube oil required and the supply pressure, the heat load to be removed by the oil, and the nameplate power rating, operating power rating, and operating power requirements of auxiliary drivers. Approximate data shall be defined and clearly identified as such.

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

k) Description of the tests and inspection procedures for materials as required by 4.10.1.3.

l) Description of special requirements, as outlined in the purchaser's inquiry and in 4.1.3, 4.1.4, 4.1.6, 4.1.11, 4.3.2, 4.3.4, 4.5.3.1, 4.9.2, 4.9.5, 4.10.1.1, 4.10.1.2, 4.10.1.3, 5.6.1.4, 5.6.1.16, 5.6.2.1.6, 5.6.2.5.6, 5.6.2.6.2.2, 5.6.2.6.2.4, 5.7.5.3, 5.8.7.4.2, 5.8.6, 6.1.3, 6.3.2, 6.4.1, and any other paragraph in the purchaser's inquiry.

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

n) Start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

o) Vibration limits per 4.5.7.2.1 and 4.5.7.3.1.

p) As a minimum, the vendor shall include the following data for gas turbine inlet filtration system:

1) manufacturer and model number or type for the filter housing and filters (if not the same),

2) materials of construction and description of the acoustic insulation,

3) coatings (if required),

4) system filtration efficiency (cleanliness),

5) pressure drop of each filter section (clean),

6) alarm and trip set point for maximum filter differential pressure,

7) total pressure drop of filter ducting system measured at bell mouth intake,

8) average air flow velocity at filter housing inlet and at media face,

9) weights and dimensions.

q) Recommendation for de-icing, if applicable.

r) Expected exhaust temperature and corresponding mass flow.

s) Extent of component removal required for combustion system maintenance.

t) Recommended inspection and maintenance intervals, as applicable. As a minimum, the following data shall be provided:

1) inspection tasks as a function of fired hours,

2) required preventive maintenance procedures during inspection and parts to be renewed and/or replaced,

3) expected duration of shutdown for each required maintenance procedure with the associated number of people and work schedule required for the stated duration,

4) effects of multiple starts on inspection intervals and engine life,

5) estimated nonrecoverable decrease in output that may be expected over the life of the gas turbine due to fouling of the compressor and deterioration of power turbine.

u) Details of the preparation of the equipment for shipment and storage at the site prior to commissioning.

• v) When specified, the vendor shall include a probabalistic spare parts optimization analysis based on failure rates supported by inventory histories for the model being supplied.

• w) If specified, the vendor shall include in the proposal failure modes and effects analysis (FMEA) to address major failure modes of the equipment train being offered.

● x) If specified, the vendor shall include a life cycle cost analysis based on assumed energy costs documented in the report. The analysis shall be over 15 years and based on a discount rate of 9 %.

● 7.2.4 Curves

The proposal shall contain a power output vs speed curve for the site rated conditions. It should follow the format shown in Figure 14, Figure 15, or Figure 16 as applicable. Additional curves shall be presented showing site rated power and speed at specified maximum and minimum site ambient temperatures (see 4.1.19) and showing both using specified fuels (see 5.8). All curves shall include power deductions (or fuel increases) for inlet and exhaust pressure losses to reflect the inlet and exhaust equipment that is specified or proposed. If specified, the curves described in Item a) through Item f) below shall also be furnished.

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

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

● c) Curves showing the effect of full-range ambient conditions on exhaust flow and temperature.

● d) Run-down curves showing exhaust flow and temperature vs time after trip, under full load and no load initial conditions.

NOTE Run-down parameters for two-shaft machines can be measured during a mechanical run test. However, the inertia and rundown load for a single-shaft turbine may not be available during a mechanical run test.

● e) NO_x and CO_2 emission curves showing concentration in the exhaust gas vs percentage load at each specified temperature.

● f) Impact of anti-icing system operation on power vs speed curve, if applicable.

7.2.5 Options

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

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

7.3 Contract Data

7.3.1 General

7.3.1.1 The contract data to be furnished by the vendor is specified in Annex B. Each drawing shall have a title block in its lower right-hand corner that shows the date of issuance, a reference to all identification data as specified in 7.1.2, the revision number and date, and the title. The other documents, not in a drawing format, such as bill of material, datasheets, etc. shall include identification data as specified in 7.1.2, including revision history.

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

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

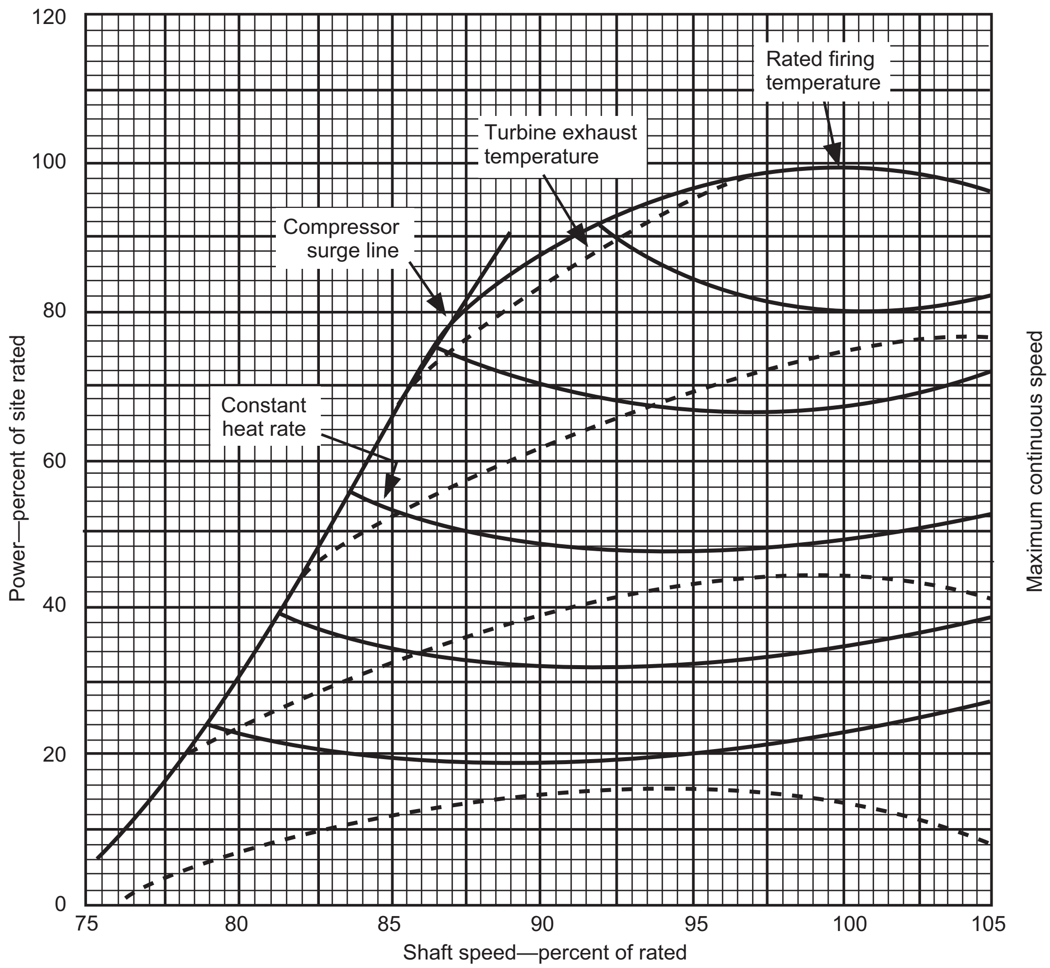


Figure 14—Performance Curves for a Single-shaft Gas Turbine

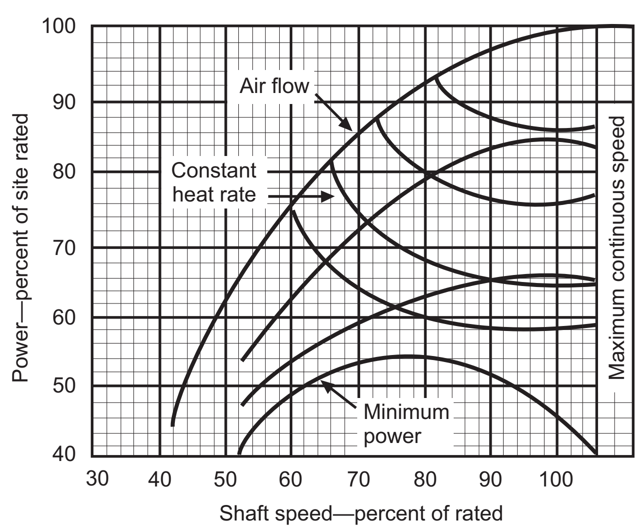


Figure 15—Performance Curves for a Multiple-shaft Gas Turbine (Constant Exhaust Temperature)

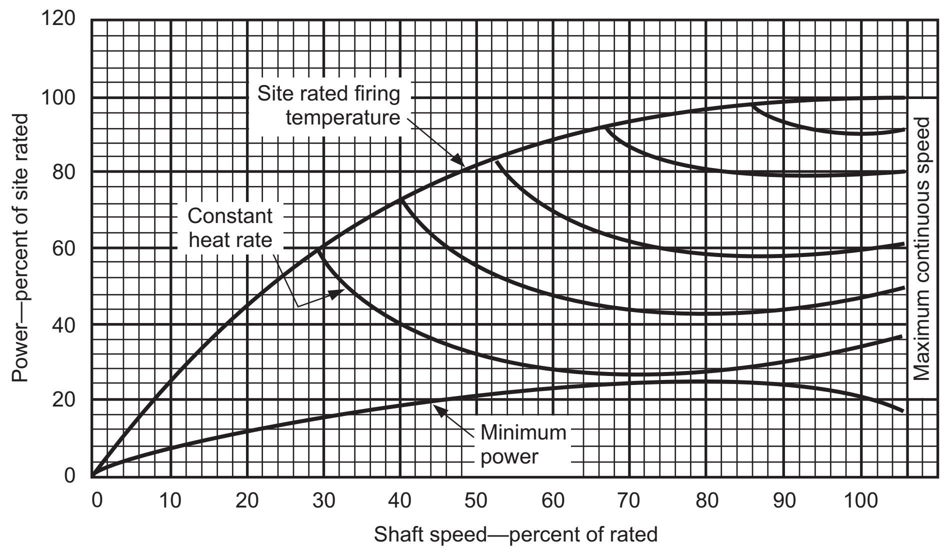


Figure 16—Performance Curves for a Multiple-shaft Gas Turbine (Varying Exhaust Temperature)

7.3.2 Drawings

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

7.3.3 Technical Data

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

• 7.3.4 Progress Reports

The vendor shall submit progress reports to the purchaser at the intervals specified on the VDDR form as per Annex B.

7.3.5 Parts Lists and Recommended Spares

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

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

7.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

7.3.6.1 General

The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference-identifying data specified in 7.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation (see 4.1.19).

7.3.6.2 Installation Manual

Any special information required for proper installation design that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time that is mutually agreed upon in the order but not later than the final issue of prints. The manual shall contain information such as special alignment and grouting procedures, utility specifications (including quantities), and all other installation data, including the drawings and data specified in 7.3.2 and 7.3.3. The manual(s) shall clearly identify the locations of all lifting points and lifting lugs. Weights, dimensions, and center of gravity shall be readily identifiable. Where necessary instructions, drawings, data, procedures or other means for the safe handling, unloading, and maintenance of that package shall also be included.

7.3.6.3 Operating and Maintenance Manual

Manual(s) containing operating and maintenance data shall be forwarded at a time mutually agreed upon by the purchaser and the vendor, but no later than shipment. One manual shall accompany each unit at shipment. This manual shall include a section that provides special instructions for operation at specified extreme environmental conditions, such as temperatures (see 4.1.19). The manual shall include centers of gravity and rigging provisions to permit the removal of the top half of casings, rotors, and any subassemblies that weigh more than 135 kilograms (300 lb). As a minimum, the manual shall also include all the data listed in Annex B.

• 7.3.6.4 Technical Data Manual

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

Annex A
(informative)

Typical Datasheets

	JOB NO. ____ ITEM NO. ____
	PURCHASE ORDER NO. ____
	SPECIFICATION NO. ____
COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **S I UNITS**	REVISION NO. ____ DATE ____
	PAGE ____ OF ____ BY ____

No.		
1	**APPLICABLE TO:** ○ PROPOSAL ○ PURCHASE ○ AS-BUILT	
2	FOR ____	UNIT ____
3	SITE ____	SERIAL NUMBER ____
4	SERVICE ____	NUMBER REQUIRED ____
5	○ CONTINUOUS ○ INTERMITTENT ○ STANDBY	DRIVEN EQUIPMENT ____
6	MANUFACTURER ____ MODEL ____	ISO RATING (3.21) ____ kW @ ____ r/min
7	NOTE: INFORMATION TO BE COMPLETED: ○ BY PURCHASER	☐ BY MANUFACTURER ☐ BY MFR IF NOT BY PURCHASER
8	**GENERAL**	
9	**CYCLE:** ○ REGEN ○ SIMPLE ○ EXHAUST HEAT RECOVERY TYPE: ____	☐ SINGLE SHAFT ☐ MULTI SHAFT
10	DRIVEN EQUIPMENT POWER: NORMAL SHAFT ____ kW @ ____ r/min	RATED SHAFT ____ kW @ ____ r/min
11	GAS TURBINE DRIVER OUTPUT SHAFT SPEED RANGE (4.1.5) ○ MIN ____ r/min	○ MAX ____ r/min
12	○ DESIRED MINIMUM SITE POWER ____ kW ____ r/min	○ ____
13	OPERATION ○ ATTENDED ○ UNATTENDED	☐ POTENTIAL MAXIMUM POWER (3.41) ____ kW
14	**NOTE:** All Datasheets References to GG = Gas Generator, SS = Single Shaft, and PT = Power Turbine	
15	**PERFORMANCE**	**LOCATION** (4.1.19)
16	**GAS TURBINE INCLUDING ALL LOSSES**	○ INDOOR ○ OUTDOOR ○ GRADE
17	○ INLET LOSS ____ mm H_2O EXHAUST LOSS ____ mm H_2O	○ HEATED ○ UNDER ROOF ○ MEZZANINE
18	○ INLET AIR CHILLER DESIGN RATING ____	○ UNHEATED ○ PARTIAL SIDES ○ OTHER ____
19	SITE / NORMAL / SITE / SITE	○ AMBIENT TEMPERATURE RANGE (°C) (5.1.2.1)
20	RATED / DUTY / MAX / MIN	MINIMUM ____ NORMAL ____ MAXIMUM ____
21	(3.52) / (3.32) / TEMP / TEMP	○ EXTREME AMBIENT TEMPERATURES (°C) (5.1.2.1)
22	○ DRY BULB TEMP (AMB) °C ____ ____ ____ ____	MINIMUM ____ MAXIMUM ____
23	○ TURBINE INLET AIR CHILLED (Y/N) ____ ____ ____ ____	○ SEISMIC DESIGN ZONE ____
24	○ TURBINE INLET TEMP °C ____ ____ ____ ____	○ WIND DESIGN VELOCITY m/s ____
25	○ RELATIVE HUMIDITY (AMB) % ____ ____ ____ ____	○ ELEVATION ____ m ○ PRECIPITATION ____
26	○ BAROMETRIC PRESS kPa ____ ____ ____ ____	ELECTRICAL AREA CLASSIFICATION(4.1.14)
27	☐ GT OUTPUT SHAFT POWER kW ____ ____ ____ ____	○ UNCLASSIFIED ○ HAZARDOUS
28	☐ GG OUTPUT SHAFT SPEED r/min ____ ____ ____ ____	APPLICABLE CODE: (5.4.1.5.3) ○ NEC 500 ○ NEC 505 ○ IEC
29	☐ PT OUTPUT SHAFT SPEED r/min ____ ____ ____ ____	ZONE ____ GROUP: ____ TEMP. CODE: ____
30	☐ LHV HEAT RATE kJ/kW-hr ____ ____ ____ ____	AREA CLASSIFICATION ○ ____
31	☐ LHV EFFICIENCY % ____ ____ ____ ____	AREA CLASSIFICATION ENCLOSURE INTERIOR ○ ____
32	☐ FIRING TEMPERATURE °C ____ ____ ____ ____	○ THIRD-PARTY CERTIFICATION REQUIRED
33	☐ AIR FLOW kg/s ____ ____ ____ ____	○ WINTERIZATION REQD ○ TROPICALIZATION REQD (5.4.6.6)
34	☐ GG EXHAUST TEMP °C ____ ____ ____ ____	**UNUSUAL CONDITIONS:**
35	☐ PT EXHAUST FLOW kg/s ____ ____ ____ ____	○ DUST ○ FUMES
36	☐ PT EXHAUST TEMP °C ____ ____ ____ ____	○ NORMAL / MAX DUST LOADING kg/Nm^3/hr ____
37	☐ FUEL FLOWRATE kg/hr ____ ____ ____ ____	○ SNOW LOAD kg/m^2 ____
38	○ CERTIFIED POINT (3.32) ____ ____ ____ ____	**NOISE LIMIT REQUIREMENTS:** (4.1.10)
39	INCLUDING ○ STEAM ○ WATER EFFECTS FOR	○ GAS TURBINE ENCLOSURE ____ dBA ○ PRESSURE ○ POWER
40	☐ EMISSION CONTROL ☐ AUGMENTATION (4.1.9)	○ INLET SYSTEM ____ dBA ○ PRESSURE ○ POWER
41	☐ STEAM FLOW, kg/hr ____ ____ ____	○ EXHAUST SYSTEM ____ dBA ○ PRESSURE ○ POWER
42	☐ WATER FLOW, m^3/hr	____
43	**APPLICABLE SPECIFICATIONS:**	**PAINTING:**
44	○ API 616 GT FOR THE PETROLEUM, CHEMICAL, & GAS INDUSTRY SERVICES	○ MANUFACTURER'S STANDARD
45	○ GOVERNING SPECIFICATION (IF DIFFERENT) ____	○ MANUFACTURER'S STANDRAD FOR MARINE ENVIRONMENT
46	____	**MISCELLANEOUS:**
47	○ VENDOR HAVING UNIT RESPONSIBILITY (4.1.2) ____	○ BOLT THREADING (4.2.7.1)
48	○ OTHER ____	THREADED OPENINGS & BOSSES (4.4.3.4): ○ ISO ○ ASME
49	**SHIPMENT:** (6.4)	ISO 7-1:1994 THREADS (4.4.3.4): ○ TAPERED ○ STRAIGHT
50	○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED	IRON FLANGES (4.4.5.1): ○ ISO ○ ASME
51	○ OUTDOOR STORAGE MORE THAN 6 MONTHS (6.4.1)	MACHINED & STUDDED CONNECTIONS (4.4.6): ○ ISO ○ ASME
52	SPARE ROTOR ASSEMBLY PACKAGED FOR (6.4.3.10)	○ PURCHASER REVIEW OF CAMPBELL / GOODMAN DIAGRAM (4.5.3.4)
53	○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT	○ LOW TEMPERATURE MATERIALS REQ'D (4.10.5.1)
54	COMMENTS:	

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COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **S I UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

FUEL SYSTEM (5.8)

TYPE ○ GAS (5.8.2) ○ LIQUID (5.8.3) ○ DUAL (5.8.5.1)

DUAL SYSTEM REQMTS (5.8.5.1) ○ GAS/GAS ○ LIQUID/GAS ○ LIQUID/LIQUID

○ FUEL GAS COMPRESSION SYSTEM REQ'D [5.8.1.2.1.3 c)] ○ MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER ______ seconds

GAS FUELS (5.8.2)

○ HC DEW PT,ºC @ kPa ______ ______ ______

○ FUEL ANALYSIS - MOL % (5.8.2.1)

COMPOSITION:	M.W.	NORMAL	START-UP	ALTERNATE
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			
N-BUTANE	58			
I-PENTANE	72			
N-PENTANE	72			
HEXANE PLUS				
TOTAL	%	**100.00**	**100.00**	**100.00**
AVG. MOL. WT.				
○ LHV (5.8.2.4.1)	BTU/SCF			
☐ REQ'D FUEL TEMP	ºC			
☐ WOBBE INDEX REQ'D				
☐ FUEL PRESSURE REQUIRED	kPag			

CONTAMINENTS (5.8.2.2.1)				
○ TAR	PPM			
○ CARBON BLACK	PPM			
○ COKE	PPM			
○ SOLIDS	PPM			
○ NAPHTHALENE	PPM			
○ GAS HYDRATES	PPM			
○ ______	PPM			
CORROSIVE AGENTS (5.8.2.3.1)	PPM			
○ HYD. SULPHIDE	PPM			
○ SULPHUR DIOXIDE	PPM			
○ SULPHUR TRIOXIDE	PPM			
○ TOTAL SULPHUR	PPM			
○ ALKALI METALS	PPM			
○ CHLORIDES	PPM			

GAS FUEL SYSTEM AND COMPONENTS

- ○ FUEL GAS BYPASS & VENT [5.8.1.2.1.3 d)]
- ☐ MANUAL ISOLATION VALVE MFR (5.8.1.2.2) ______
- ○ SECONDARY VENT VALVE ______
- ☐ PRIMARY FAST SHUT OFF MFR (5.8.1.2.4) ______
- ☐ LEAK TIGHT SHUT OFF MFR (5.8.1.2.4) ______
- ☐ EXTERNAL SHUT OFF VALVE MFR (5.8.1.2.5) ______
- ○ DUAL Y-TYPE STRAINERS REQ'D (5.8.1.2.6.2)

HEATER REQD (5.8.2.7) ☐ YES ☐ NO

- ☐ MANUFACTURER ______
- ☐ REQ'D FUEL TEMP ABOVE DEW POINT ______
- ○ COALESCING FILTER (5.8.2.2.3)
  - ☐ MANUFACTURER ______
- ○ RATE OF CHANGE OF LHV (5.8.2.4.2) ______

FUEL ANALYZER EQUIPMENT:

- ○ CALORIMETER
- ○ GAS CHROMATOGRAPH
- ○ WOBBE METER

○ SUPPLY FILTRATION (5.8.1.2.6) ______

PIPING, TUBING & DESIGN DETAILS

- ○ PRESENCE OF HYDROGEN SULFIDE ______
- ○ NACE MATERIAL STANDARDS (4.10.1.9) ______
- ○ ANSI FLANGE RATING ______
- ○ PIPING / TUBING GRADE ______
- ○ TUBE FITTING MANUFACTURER ______
- ○ MAXIMUM VENT BACKPRESSURE (5.8.1.2.8) ______ kPag

"SHIP LOOSE" FUEL GAS SYSTEM COMPONENTS

- ☐ Y-TYPE STRAINERS ______
- ☐ DUPLEX FUEL GAS FILTERS ______
- ☐ PIPING ______
- ☐ HEATERS ______
- ☐ GAS ANALYSIS EQUIPMENT ______

REMARKS: ______

2

	JOB NO. ____ ITEM NO. ____
COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **S I UNITS**	REVISION ____ DATE ____ PAGE ____ OF ____ BY ____

FUEL SYSTEM (5.8)

TYPE ○ GAS (5.8.2) ○ LIQUID (5.8.3) ○ DUAL (5.8.5.1)

DUAL SYSTEM REQMTS (5.8.5.1) ○ GAS/GAS ○ LIQUID/GAS ○ LIQUID/LIQUID

○ MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER ____ seconds

LIQUID FUEL SYSTEM (5.8.3)	**LIQUID FUELS (5.8.4)**
FUEL GRADES (5.8.4.3):	LIQUID FUEL TREATMENT REQUIRED ☐ YES ☐ NO
○ ASTM D2880 GRADE (5.8.4.3.1)	TREATMENT SYSTEM BY ○ VENDOR ○ OTHER ____
○ GRADE 0-GT ____	____
○ GRADE 1-GT ____	HEATER REQUIRED (5.8.3.14) ☐ YES ☐ NO
○ GRADE 2-GT ____	☐ LIQUID FUEL PRESS REQUIRED, MAX/MIN, kPag ____
○ GRADE 3-GT ____	☐ **FUEL ANALYSIS DATA** (5.8.4.3) ASTM METHOD ○ MEASURED VALUE
○ GRADE 4-GT ____	PROPERTY
○ ASTM D1655 (5.8.4.3.2) ____	VISCOSITY, cSt @ 38°C D-445 ○ ____
○ JET A OR JET A-1 ____	DISTILLATION DATA D-86
○ JET B ____	10% / 50% / 90% RECOVERY, °C MAX ○ ____
○ OTHER, INDICATE ANALYSIS (5.8.4.3.3) ____	END POINT, °C MAX ○ ____
____	SULFUR CONTENT %WEIGHT, MAX. (SELECT APPL. METHOD)
____	BOMB METHOD D-129 ○ ____
☐ ISOLATION VALVE LOCATION (5.8.3.2)	LAMP METHOD D-1266 ○ ____
____	HIGH-TEMP METHOD D-1552 ○ ____
☐ FLOW CONTROL DEVICE (5.8.3.3)	CARBON RESIDUE (ON 10%
____	BOTTOMS) % WT. MAX. ○ ____
☐ SHUT-OFF VALVE (5.8.3.4) ____	CONRADSON D-189 ○ ____
☐ SPILL VALVE (5.8.3.4) ____	RAMSBOTTOM D-524 ○ ____
☐ DRAIN VALVE (5.8.3.6) ____	COPPER STRIP CORROSION PLATE D-130
☐ FILTER / STRAINER (5.8.3.7) ____	3 HOURS AT 100°C MAXIMUM ○ ____
____	AROMATIC CONTENT % WT D-5186 ○ ____
☐ VALVE PROVING & POSITION MONITORING (5.8.3.8) ____	ASH CONTENT D-482 ○ ____
☐ THERMAL RELIEF VALVES (5.8.3.9) ____	SPECIFIC GRAVITY, kg/m^3 @ 15°C D-4052 ○ ____
☐ MULTI FUEL SYSTEMS (5.8.3.10) ____	FLASH POINT, °C D-56 ○ ____
☐ FUEL PURGING (5.8.3.11)	CLOUD POINT, °C D-2500 ○ ____
____	POUR POINT, °C D-97
☐ FUEL DRAINAGE (5.8.3.12) ____	WATER D-95 ○ ____
☐ OTHER SYSTEM COMPONENTS (5.8.3.13)	PARTICULATES, MG/100ML D-2276 ○ ____
____	TRACE METALS (ATOMIC
____	ABSORPTION PREFERRED) D-3605 ○ ____
____	SODIUM ○ ____
○ FUEL TRANSFER EQUIP REQUIRED (5.8.3.15)	POTASSIUM ○ ____
	VANADIUM ○ ____
FUEL PUMP SYSTEM DETAILS	CALCIUM ○ ____
○ FUEL PUMP REQUIRED ____	LEAD ○ ____
○ RV AT PUMP DISCHARGE (YES/NO) ____	OTHER METALS ____ ○ ____
○ RV SET POINT bar ____	LOWER HEATING VALUE, MJ/kg D-2382 ○ ____
○ PUMP RATED CAPACITY l/min ____	REID VAPOR PRESSURE, Bar D-323 ○ ____
	OLEFIN CONTENT, % VOL D-1319 ○ ____
PIPING, TUBING & DESIGN DETAILS	
○ PRESENCE OF HYDROGEN SULFIDE ____	**REMARKS:** ____
○ NACE MATERIAL STANDARDS (4.10.1.9) ____	____
○ ANSI FLANGE RATING ____	____
○ PIPING / TUBING GRADE ____	____
○ TUBE FITTING MANUFACTURER	

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COMBUSTION GAS TURBINE (API 616-5th)
DATASHEET
S I UNITS

CONSTRUCTION FEATURES

○ SPEEDS:
MAX. CONT. ______ r/min TRIP ______ r/min
☐ LATERAL CRITICAL SPEEDS (DAMPED)
FIRST CRITICAL ______ r/min ______ r/min
SECOND CRITICAL ______ r/min ______ r/min
THIRD CRITICAL ______ r/min ______ r/min
FOURTH CRITICAL ______ r/min ______ MODE
☐ PROTOTYPE OR MODIFIED ROTOR SUPPORT (4.7.1)
○ TRAIN LATERAL ANALYSIS REQUIRED (4.7.2.6)
○ TRAIN TORSIONAL ANALYSIS REQUIRED (4.7.3.1)
☐ TORSIONAL CRITICAL SPEEDS:
FIRST CRITICAL ______ r/min
SECOND CRITICAL ______ r/min
THIRD CRITICAL ______ r/min
FOURTH CRITICAL ______ r/min
VIBRATION: (4.7.5.2.1) (4.7.5.3.1) [7.2.3 o)]:
☐ ACCEPTANCE LIMITS: SHAFT ______ µm P-P
CASE ______ mm/s

☐ ROTATION, VIEWED FROM DRIVE END ☐ CW ☐ CCW

AIR COMPRESSOR:
STAGES ______ MAXIMUM TIP SPEED ______ m/s
TYPE ______ PRESSURE RATIO ______
CASING SPLIT (4.2.3) ☐ AXIAL ☐ RADIAL
ROTOR ☐ SOLID ☐ BUILT UP

TURBINE:
STAGES ______ MAX. TIP SPEED ______ m/s
CASING SPLIT (4.2.3) ☐ AXIAL ☐ RADIAL
ROTOR ☐ SOLID ☐ BUILT UP

COMBUSTORS: (4.3.2) ○ DRY LOW EMISSIONS REQUIRED
☐ SINGLE ☐ MULTIPLE, NUMBER ______
☐ GAS ☐ LIQUID ☐ DUAL FUEL
☐ FUEL NOZZLES PER COMBUSTOR ______
☐ CONFIGURATION ______
☐ MAXIMUM ALLOWABLE TEMP. VARIATION ______ °C
APPLICABLE PLANE ______
☐ WOBBE INDEX REQD (4.3.7) ☐ MAX MIN

COMBUSTION SYSTEM DETAILS:

REMARKS:

MATERIALS OF CONSTRUCTION (4.10)

COMPRESSOR ROTOR BLADES ______
COMPRESSOR STATOR VANES ______
COMPRESSOR BLADE/VANE COATING ______
GG SHAFT ______ PT SHAFT ______
GG COMPRESSOR CASING ______
GG HPT CASING ______ PT CASING ______
COMBUSTOR LINER ______
COMBUSTOR HEAT SHIELD ______
GG HP TURBINE (HPT) and POWER TURBINE (PT):

TURBINE STAGE	NOZZLES	BLADES	DISKS or SHROUDS
HPT-S1			
HPT-S2			
PT-S1			
PT-S2			

BALANCING:
○ LOW SPEED BALANCING (4.7.4.2)
○ HIGH SPEED BALANCING (4.7.4.3.1)
ACCEPTANCE CRITERIA (4.7.4.3.2)
○ GRADE 2.5 ○ ISO 11342 ○ 1.0 mm/s
○ LOW SPEED RESIDUAL BALANCE CHECK (4.7.4.3.4)

MAINTENANCE INTERVALS, HOURS / DURATION, HOURS

☐ BORESCOPE INSP. ______ / ______
☐ HOT SECTION OVERHAUL ______ / ______
☐ MAJOR OVERHAULS ______ / ______

REMARKS:

FOR MULTIPLE SHAFT TURBINES PROVIDE DATA FOR EACH SHAFT

4

	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **S I UNITS**	REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

GAS GENERATOR - CONSTRUCTION FEATURES

BEARINGS AND BEARING HOUSINGS (4.8)

RADIAL BEARINGS		DE	NDE	RADIAL / THRUST		RADIAL	THRUST
		BRG No.	BRG No.			BRG No.	BRG No.
☐ TYPE				☐ TYPE			
☐ MANUFACTURER				☐ MANUFACTURER			
☐ SIZE	mm			☐ SIZE	mm		
☐ RATED SHAFT SPEED	r/min			☐ RATED SHAFT SPEED	r/min		
☐ RADIAL LOAD	N			☐ RADIAL/THRUST LOAD	N		
☐ BEARING 'C' RATING	N			☐ BEARING 'C' RATING	N		
☐ L-10 BEARING LIFE	hr			☐ L-10 BEARING LIFE	hr		
☐ INNER / OUTER RACE MAT'L				☐ INNER / OUTER RACE MAT'L			
☐ ROLLING ELEMENT MAT'L				☐ ROLLING ELEMENT MAT'L			
☐ CAGE MATERIAL				☐ CAGE MATERIAL			

☐ BEARING SPAN (BETWEEN BRG No.X and No.Y) ______ mm

☐ OTHER

LUBRICATION: ☐ FLOODED ☐ DIRECTED

THRUST COLLAR: ☐ INTEGRAL ☐ REPLACEABLE

BEARING TEMPERATURE SENSORS (4.8.5.5)

○ SEE ATTACHED API-670 DATASHEETS
○ THERMOCOUPLES
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ RESISTANCE TEMPERATURE DETECTORS ______
○ RESISTANCE MATL ______ ○ ______ OHMS
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ LOCATION-JOURNAL BEARING:
NUMBER ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ LOCATION-THRUST BEARING
NO. (ACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
NO.(INACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ MONITOR SUPPLIED BY (5.4.7.5) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RANGE ______ ☐ ALARM SET @ ______ °C
○ SHTDWN ☐ SET @ ______ °C ☐ TIME DELAY ____ seconds

CASING AND / OR ROLLING ELEMENT VIBRATION TRANSDUCERS (5.4.7.8)

○ SEE ATTACHED API-670 DATASHEETS
○ CASING VIBRATION (5.4.7.8.3) ○ ROLLING ELEMENT VIB. (5.4.7.8.5)
○ MFR ______ ○ MODEL ______
○ LOCATION ______ ○ NUMBER ______
○ MONITOR SUPPLIED BY (5.4.7.8.4) ______
○ MONITOR SUPPLIED BY (5.4.7.8.6) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ mm/s
○ SHTDWN ☐ SET @ ______ mm/s ☐ TIME DELAY ____ seconds

PROXIMITY PROBES (4.8.5.3)

RADIAL SHAFT VIBRATION PROBES

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______
○ NO. AT EACH SHAFT BRG ______ TOTAL NO. ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ______ µm
○ SHUTDWN ☐ SET @ ____ microns ☐ TIME DELAY ____ seconds

AXIAL POSITION PROBES (4.8.5.3)

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______ ○ NO. REQUIRED ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ______ µm
○ SHUTDWN ☐ SET @ microns ☐ TIME DELAY ____ seconds

REMARKS: ______

COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **S I UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

POWER TURBINE - CONSTRUCTION FEATURES

BEARINGS AND BEARING HOUSINGS (4.8)

RADIAL		DE BRG No.	NDE BRG No.
☐ TYPE			
☐ MANUFACTURER			
☐ SHAFT DIAMETER	mm		
☐ BEARING LENGTH	mm		
☐ AREA,	mm^2		
☐ UNIT LOAD (ACT/ALLOW)	N/mm^2		
☐ BASE MATERIAL			
☐ BABBITT THICKNESS	mm		
☐ NO. PADS			
☐ LOAD: BETWEEN/ON PAD			
☐ PIVOT: CENTER/OFFSET	%		

☐ BEARING SPAN (BETWEEN BRG No.X and No.Y) ______ mm

☐ DAMPER BEARING

THRUST		ACTIVE DE/NDE	INACTIVE DE/NDE
☐ TYPE			
☐ MANUFACTURER			
☐ SHAFT DIAMETER	mm		
☐ BEARING SIZE	mm		
☐ AREA	mm^2		
☐ UNIT LOAD (ACT/ALLOW)	N/mm^2		
☐ BASE MATERIAL			
☐ BABBITT THICKNESS	mm		
☐ NO. PADS			
PIVOT: CENTER/OFFSET	%		

LUBRICATION: ☐ FLOODED ☐ DIRECTED

THRUST COLLAR: ☐ INTEGRAL ☐ REPLACEABLE ______

BEARING TEMPERATURE SENSORS (4.8.5.5)

○ SEE ATTACHED API-670 DATASHEETS
○ THERMOCOUPLES
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ RESISTANCE TEMPERATURE DETECTORS ______
○ RESISTANCE MAT'L ______ ○ ______ OHMS
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ LOCATION-JOURNAL BEARING:
NUMBER ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ LOCATION-THRUST BEARING
NO. (ACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
NO.(INACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ MONITOR SUPPLIED BY (5.4.7.5) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RANGE ______ ☐ ALARM SET @ ____ °C
○ SHTDWN ☐ SET @ ____ °C ☐ TIME DELAY ____ seconds

CASING AND / OR ROLLING ELLEMENT VIBRATION TRANSDUCERS (5.4.7.8)

○ SEE ATTACHED API-670 DATASHEETS
○ CASING VIBRATION (5.4.7.8.3) ○ ROLLING ELEMENT VIB. (5.4.7.8.5)
○ MFR ______ ○ MODEL ______
○ LOCATION ______ ○ NUMBER ______
○ MONITOR SUPPLIED BY (5.4.7.8.4) ______
○ MONITOR SUPPLIED BY (5.4.7.8.6) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ☐ ______ ○ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ mm/s
○ SHTDWN ☐ SET @ ____ mm/s ☐ TIME DELAY ____ seconds

PROXIMITY PROBES (4.8.5.3)

RADIAL SHAFT VIBRATION PROBES

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______
○ NO. AT EACH SHAFT BRG ______ TOTAL NO. ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
MFR ______ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ ____ microns ☐ TIME DELAY ____ seconds

AXIAL POSITION PROBES (4.8.5.3)

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______ ○ NO. REQUIRED ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ ____ microns ☐ TIME DELAY ____ seconds

REMARKS:

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COMBUSTION GAS TURBINE (API 616-5 th) DATASHEET S I UNITS	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

UTILITIES

○ **UTILITY CONDITIONS:**

STEAM:		**AUXILIARY DRIVERS**		**HEATING**	
INLET MIN	MPag	°C		MPag	°C
NORM	MPag	°C		MPag	°C
MAX	MPag	°C		MPag	°C
EXHST MIN.	MPag	°C		MPag	°C
NORM	MPag	°C		MPag	°C
MAX	MPag	°C		MPag	°C
	STARTING			**INJECTION**	
INLET MIN	MPag	°C		MPag	°C
NORM	MPag	°C		MPag	°C
MAX	MPag	°C		MPag	°C
EXHST MIN.	MPag	°C			
NORM	MPag	°C			
MAX	MPag	°C			

○ INLET AIR HUMIDIFICATION (IAH) WATER:

INLET TEMPERATURE ______ °C

DESIGN TEMPERATURE ______ °C

NORM PRESS ______ MPag

DESIGN PRESS ______ MPag

○ COOLING WATER:

INLET TEMPERATURE ______ °C MAX RETURN ____ °C

DESIGN TEMPERATURE ______ °C

NORM PRESS ______ MPag MIN RETURN ______ MPag

DESIGN PRESS ______ MPag MAX ALLOW Δ P ______ Mpa D

WATER SOURCE ______

○ INLET AIR CHILLING (IAC) WATER:

INLET TEMPERATURE ______ °C MAX RETURN ____ °C

DESIGN TEMPERATURE ______ °C

NORM PRESS ______ MPag MIN RETURN ______ MPag

DESIGN PRESS ______ MPag MAX ALLOW Δ P ______ MPag

☐ **TOTAL UTILITY CONSUMPTION:**

IAH / COOLING / IAC WATER ____ / ____ / ____ m^3/hr

STEAM LEVEL ____ MPag ____ MPag ____ MPag

STEAM, NORMAL ____ kg/hr ____ kg/hr ____ kg/hr

STEAM, MAX ____ kg/hr ____ kg/hr ____ kg/hr

INSTRUMENT AIR ______ Nm^3/hr

NITROGEN ______ Nm^3/hr

MOTORS (AUXILIARIES) ______ kW

BATTERY CHARGERS ______ kW

HEATERS ______ kW

TURBINE AIR EXTRACTION REQUIRED: (4.1.22)

○ Nm^3/hr ______ @ ______ MPag

☐ MAXIMUM PRESSURE AVAILABLE AT MINIMUM SPEED: MPag

☐ MINIMUM SPEED: ______ r/min

☐ DISCHARGE TEMPERATURE ______ °C

☐ COMPRESSOR EXTRACTION STAGE NUMBER: ______

○ INSTRUMENT AIR PRESSURE DESIGN, MPag ______

MAX ______ NORMAL ______ MIN ______

○ NITROGEN PRESSURE DESIGN, barG ______

MAX ______ NORMAL ______ MIN ______

ELECTRICITY: (5.4.6.1) ○ PILOT LIGHT INDICATORS

	MOTORS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

REMARKS: ______

PURCHASER CONNECTIONS

CONNECTION	○ DESIGN APPROVAL REQUIRED (4.10.4.7.4)	☐ SIZE	☐ FACING and RATING	☐ POSITION (4.4.1)	☐ FLANGED OR STUDDED (4.4.1)	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY m/s

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	JOB NO. ______	ITEM NO. ______	
COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **S I UNITS**	REVISION ______	DATE ______	
	PAGE ______	OF ______	BY ______

1	**INSTRUMENTS**									
2	**INSTRUMENTATION & INSTALLATION:** (5.4.1.1.)	INSTRUMENT TYPE		INSTRUMENT LOCATION			TRANS- MITTERS FURNISHED BY		CONTROL ROOM RECEIVERS FURN BY	
3	○ API 614/ISO 10438 ○ ______									
4	○ INSTRUMENTATION MOUNTING (5.4.4.7)									
5	○ OPTIONAL ALARM & SHUTDOWN POINT (5.4.4.7) SEE ADD. SHEET									
6	**DESCRIPTION**	INDICATING	RECORDING	LOCAL	LOCAL PANEL	CONTROL ROOM	VENDOR	OTHERS	VENDOR	OTHERS
7	**GAS GENERATOR OR SINGLE SHAFT GAS TURBINE**									
8	TACHOMETER(S)	○	○	○	○	○	○	○	○	○
9	Δ P AIR INLET SYSTEM	○	○	○	○	○	○	○	○	○
10	COMPRESSOR DISCHARGE PRESSURE	○	○	○	○	○	○	○	○	○
11	FUEL FILTER Δ P	○	○	○	○	○	○	○	○	○
12	FUEL SUPPLY PRESSURE	○	○	○	○	○	○	○	○	○
13	STARTING GAS SUPPLY PRESSURE	○	○	○	○	○	○	○	○	○
14	STARTING GAS EXHAUST PRESSURE	○	○	○	○	○	○	○	○	○
15	TEMP COMBUSTOR MEASUREMENT (6 PTS MIN) (4.3.2)	○	○	○	○	○	○	○	○	○
16	TEMP GAS TURB CONTROL PLANE (6 PTS MIN)	○	○	○	○	○	○	○	○	○
17	INLET AIR TEMPERATURE	○	○	○	○	○	○	○	○	○
18	TEMPERATURE, GG COMPRESSOR DISCHARGE	○	○	○	○	○	○	○	○	○
19	TEMPERATURE, THRUST BEARING OIL DRAIN	○	○	○	○	○	○	○	○	○
20	TEMPERATURE, EACH BEARING SUMP-ROLLING ELEMENT TYPE)	○	○	○	○	○	○	○	○	○
21	TEMPERATURE, FUEL MANIFOLD	○	○	○	○	○	○	○	○	○
22	TEMPERATURE, LUBE OIL RESERVOIR	○	○	○	○	○	○	○	○	○
23	FIRED HOUR METER	○	○	○	○	○	○	○	○	○
24	A) NUMBER STARTS COUNTER	○	○	○	○	○	○	○	○	○
25	B) START SEQUENCE TIMER	○	○	○	○	○	○	○	○	○
26	LUBE OIL RESERVOIR LEVEL	○	○	○	○	○	○	○	○	○
27	LUBE OIL PUMP PRESSURE INDICATORS (NO.)	○	○	○	○	○	○	○	○	○
28	LUBE OIL COOLER OIL INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
29	LUBE OIL COOLER OIL OUTLET TEMPERATURE	○	○	○	○	○	○	○	○	○
30	LUBE OIL COOLER COOLANT INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
31	LUBE OIL COOLER COOLANT OUTLET TEMPERATURE	○	○	○	○	○	○	○	○	○
32	LUBE OIL FILTER Δ P	○	○	○	○	○	○	○	○	○
33	LUBE OIL PRESSURE EACH LEVEL (NO.)	○	○	○	○	○	○	○	○	○
34	CONTROL OIL PRESSURE	○	○	○	○	○	○	○	○	○
35	SITE FLOW INDICATOR EACH DRAIN (NO.)	○	○	○	○	○	○	○	○	○
36	INLET GUIDE VANE POSITION INDICATOR	○	○	○	○	○	○	○	○	○
37	EXHAUST DUCT DIFFERENTIAL PRESSURE INDICATOR	○	○	○	○	○	○	○	○	○
38	ENCLOSURE COOLING AIR EXHAUST TEMPERATURE	○	○	○	○	○	○	○	○	○
39	**POWER TURBINE**									
40	TACHOMETER(S) (NO.)	○	○	○	○	○	○	○	○	○
41	EXHAUST TEMPERATURE (2 POINTS MIN)	○	○	○	○	○	○	○	○	○
42	JOURNAL BEARING TEMPERATURE	○	○	○	○	○	○	○	○	○
43	THRUST BEARING TEMPERATURE	○	○	○	○	○	○	○	○	○
44	BEARING DRAIN TEMPERATURE	○	○	○	○	○	○	○	○	○
45	SITE FLOW INDICATOR EACH DRAIN (NO.)	○	○	○	○	○	○	○	○	○
46	LUBE OIL INLET PRESSURE	○	○	○	○	○	○	○	○	○
47	LUBE OIL INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
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	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **S I UNITS**	REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

ALARMS AND SHUTDOWNS (5.4.4)

DESCRIPTION	APPLIES TO:		(5.4.4.8.5) FIRST OUT ANNUNCIATED POINT IN VENDOR FURNISHED CONTROL PANEL		SENSING DEVICES TO BE FURNISHED BY		INDICATING LIGHT ONLY
	SS OR GG	SEP PT	ALARM	SHUT-DOWN	VENDOR	OTHERS	
RADIAL SHAFT VIBRATION							
AXIAL THRUST POSITION							
OVERSPEED							
CASING VIBRATION							
HIGH THRUST BEARING TEMPERATURE							
HIGH RADIAL BEARING TEMPERATURE							
LOW FUEL SUPPLY PRESSURE							
HIGH FUEL FILTER Δ P							
GAS TURBINE TEMPERATURE SPREAD HIGH							
EXHAUST OVER TEMPERATURE							
FAILURE OF OVER-TEMPERATURE SHUTDOWN DEVICE							
HIGH INLET AIR Δ P EACH FILTER							
COMBUSTOR FLAME-OUT							
CHIP DETECTOR, ANTI FRICTION BEARING							
FAILURE STARTING CLUTCH TO ENGAGE OR DISENGAGE							
LOW OIL PRESSURE							
HIGH LUBE OIL TEMPERATURE							
LOW LUBE OIL RESERVOIR LEVEL							
HIGH LUBE OIL RESERVOIR LEVEL							
HIGH OIL FILTER Δ P							
LUBE OIL SPARE PUMP OPERATING							
LOW CONTROL OIL PRESSURE							
LOW STARTING GAS PRESSURE							
ANTI-ICING SYSTEM - NOT OPERATING							
LOW D.C. VOLTAGE							
EMERGENCY D.C. PUMP OPERATING							
RESERVOIR HEATER "ON"							
IMPLOSION DOOR OPEN							
EXTERNAL PERMISSIVE START SIGNAL							
EXTERNAL SHUTDOWN SIGNAL							
LOSS OF AUXILIARY COOLING AIR							
LAMP TEST PUSH BUTTON							
ENCLOSURE HIGH TEMPERATURE							
CONTROL SIGNAL FAILURE							
CONTROL SYSTEM ACTUATOR FAILURE							
GOVERNOR FAILURE							
ENCLOSURE VENT FAN FAILURE							
SPARE ENCLOSURE VENT FAN OPERATING							
WOBBE METER							
GAS CHROMATOGRAPH							
EXHAUST GAS ANALYZER							

NOTES: (1) VENDOR TO ADVISE METHOD OF ANNUNCIATION
(2) VDU MAY USE MESSAGE INDICATOR

GAUGE BOARD:
☐ LOCATION ______

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JOB NO. ______ ITEM NO. ______
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COMBUSTION GAS TURBINE (API 616-5th)
DATASHEET
S I UNITS

ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER

STARTING AND HELPER DRIVERS (5.1.1)

○ STARTER ONLY ○ STARTER/HELPER (5.1.1.1)
TYPE (5.1.1.4) ○ MOTOR: ○ API 541 ○ API 546 ○ IEC 60034-1
○ GAS EXPANDER ○ IC ENGINE ○ HYDRAULIC
○ GAS TURBINE ○ STARTER IS CLUTCHED (5.1.1.7)
○ HELPER RATING (5.1.2.2) ______ kW
☐ STARTER RATING (5.1.2.1) ______ kW
○ SHAFT TURNING DEVICE REQUIRED (5.1.3.1)

☐ MOTOR (STARTER ONLY):
TYPE ______ RATING ______ kW
MFR ______ MODEL ______
○ REDUCED VOLTAGE STARTING (%) (5.1.1.5)

☐ MOTOR (STARTER / HELPER):
TYPE ______ RATING ______
MFR ______ MODEL ______
○ REDUCED VOLTAGE STARTING (%) (5.1.1.5) ______

☐ GAS EXPANDER
APPLICABLE SPEC. (5.1.1.6) ______
MFR ______ MODEL ______
kW ______ MAX. GAS FLOW ______ kg/hr
TOTAL/START ______ kg
○ GAS FOR EXPANSION TURBINE: ______

		MIN	MAX	NORMAL
INLET PRESSURE	barA			
EXHAUST PRESS	barA			
GAS TEMPERATURE, °C INLET				
GAS TEMPERATURE, °C EXHAUST				
MOLECULAR WEIGHT				

SPEED CONTROL ○ GOVERNOR ○ PRESSURE REGULATOR

DESIGN DETAILS:	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 ______ barG
CASING MATERIAL ______
SEAL TYPE ______

☐ INTERNAL COMBUSTION ENGINE
TYPE ○ SPARK IGNITED ○ DIESEL
APPLICABLE SPECIFICATION (5.1.1.6) ______
MANUFACTURER ______ MODEL ______
SPEED ______ r/min POWER ______ kW

☐ STEAM TURBINE (REFERENCE API DATASHEETS)
MFR ______ MODEL ______
kW ______ MAX. STEAM FLOW ______ kg/hr
TOTAL FLOW / START ______ kg

○ GEARS: SEE SEPARATE API 613 GEAR DATASHEETS (5.2.1.1)
○ DRIVEN EQUIPMENT, SEE SEPARATE API DATASHEETS
○ FIRE PROTECTION EQUIPMENT (5.7.3.1)
○ TYPE ○ WATER MIST ○ CO_2
○ TYPE OF SENSOR ○ NUMBER OF DETECTORS
○ ULTRA VIOLET NUMBER ______
○ INFRA RED NUMBER ______
○ HEAT RISE NUMBER ______
○ ADDITIONAL LEVELS OF DETECTION (5.7.3.3)

MOUNTING PLATES (5.3)

○ TYPE (5.3.1.1) ○ SOLEPLATE ○ BASEPLATE
☐ SHIM PACK THICKNESS ______ mm

BASEPLATE (5.3.2)

○ EQUIPMENT MOUNTED ON BASEPLATE ______ (5.3.2.1)
○ GAS TURBINE, COMPRESSOR SKID(S), ACCESSORY SKID
○ SOLEPLATES REQUIRED (5.3.3.1) ○ DRIP RIM REQUIRED
○ SUB-SOLEPLATES REQUIRED (5.3.3.1) ○ LEVELING PADS (5.3.2.3)
○ COLUMN MOUNTING (5.3.2.4) (3-POINT)

ENCLOSURES (5.7.5)

○ ENCLOSURE REQUIRED
○ MATERIAL ______
○ ACOUSTICAL
○ WEATHERPROOF
○ SAFETY
○ FIRE PROTECTION
○ ADDITIONAL VENTILATION DUCTING (5.7.5.6.3) ______

COUPLINGS AND GUARDS (5.2.2)

○ SEE ATTACHED API-671 COUPLING DATASHEETS
○ COUPLINGS PER ISO 10441 (5.2.2.4)
☐ MFR ______ ☐ TYPE ______
☐ MODEL ______ ☐ GUARD SUPPLIED BY ______
☐ MAXIMUM OUTSIDE DIAMETER ______ mm
☐ HUB WEIGHT ______ kg
☐ SPACER LENGTH ______ mm ☐ SPACER WEIGHT kg ______
○ IDLING ADAPTER REQUIRED ○ SOLE PLATE REQUIRED
○ GUARD SUPPLIED BY ______
TYPE: ○ FULLY-ENCLOSED ○ SEMI-OPEN ○ OTHER ______
LUBRICATING REQUIREMENTS:
○ NON-LUBE ○ GREASE ○ CONTINUOUS OIL LUBE
QUANTITY PER HUB ______ kg or m^3/hr

REMARKS: ______

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	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **S I UNITS**	REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

1	**ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER**	
2	**INLET CONDITIONS (5.6.1)**	**INLET SYSTEM (5.6.2)**
3	**INLET METEOROLOGICAL CONDITIONS** (5.6.1.8):	○ ANTI-ICING (5.6.1.7) ○ GAS TURBINE AIR INLET SCREEN (5.6.1.14)
4	○ WIND SPEED (km/hr) & DIRECTION ______	○ SINGLE STAGE WITH PROVISION FOR FUTURE EXTRA
5	○ WIND SPEED (km/hr) & DIRECTION FOR CONTAMINANTS ______	STAGES (5.6.2.1.2): ○ YES ○ NO
6	○ DRY BULB TEMP (C): MIN ______ MAX ______	○ IMPLOSION DOOR (5.6.2.1.8)
7	○ BAROMETRIC PRESSURE (kPa) ______	○ INLET SYST. SUPPORT STEEL REQ'D. (5.6.2.1.9) MIN. HEIGHT (m) ______
8	○ RAINFALL (MAX . RATE) (mm/hr) ______	○ SEISMIC ZONE ______
9	○ SNOWFALL (MAX. RATE) (mm/hr) ______	○ SELF CLEANING (PULSE TYPE) (5.6.2.2)
10	○ RELATIVE HUMIDITY WITH VARIATIONS ______	○ RELATIVE HUMIDITY SENSOR (5.6.2.2.2)
11	○ FOG OR MIST CONDITIONS ______	○ HIGH VELOCITY INLET SYSTEM (5.6.2.3):
12	○ ICING CONDITIONS	○ HIGHER EFFICIENCY FILTERS (5.6.2.3.1)
13	**CHEMICAL CONTAMINANTS IN THE AIR** (5.6.1.9.1):	○ ADDITIONAL VANE SEPARATOR (5.6.2.3.2)
14	○ SODIUM (Na)	☐ FILTRATION EFFICIENCY ______
15	○ POTASSIUM (K)	☐ FILTER MFR. ______ MODEL ______
16	○ CALCIUM (Ca)	☐ MAINTENANCE INTERVAL ______ MONTHS
17	○ CHLORIDE (Cl)	☐ CLEANING FREQUENCY ______ DAYS
18	○ SULPHATE (SO_4)	☐ MANOMETER MFR ______ MODEL ______
19	○ NITRATE (NO_3)	RANGE ______ mm H_2O
20	○ TRACE METALS (V, Pb, Ni, Zn) ______	☐ SYSTEM SITE RATED PRESSURE DROP ______ mm H_2O
21	○ SULPHUR DIOXIDE (SO_2)	@ 110% RATED AIR FLOW AND CLEAN FILTERS
22	○ AMMONIA (NH_3)	@ 110% RATED AIR FLOW AND DIRTY FILTERS, ALARM @ ______ mm H_2O
23	○ NITROUS OXIDES (NO_X)	☐ DUCTING GAUGE / MATERIAL ______ / ______
24	○ HYDROCARBONS (VOC)	☐ EXPANSION JOINT MFR ______ TYPE ______
25	○ HYDROGEN SULPHIDE (H2S)	**INLET SILENCERS** (5.6.2.5):
26	○ CHLORINE GAS (Cl_2)	○ ALTERNATE SILENCER PLATE MATERIAL (5.6.2.5.4) ______
27	○ HYDROCHLORIC ACID (HCL)	☐ SILENCER MFR ______ Δ P ______ mm H_2O
28	○ NEON (Ne)	☐ SILENCER MATERALS ______
29	○ OZONE (O_3)	**INLET COOLERS** (5.6.2.6):
30	○ HELIUM (He)	○ EVAPORATIVE TYPE (5.6.2.6.1.1)
31	○ METHANE (CH_4)	○ LIQUID-TO-AIR TYPE (5.6.2.6.2.1)
32	○ KRYPTON (Kr)	COOLANT-SIDE CONDITIONS (5.6.2.6.2.3):
33	○ HYDROGEN (H_2)	○ MAX. AVAILABLE FLOW (L/MIN) ______
34	○ NITROUS OXIDE (N_2O)	○ MAX. TEMP (C) ______ MIN TEMP (C) ______
35	○ CARBON MONOXIDE (CO)	○ MAX. PRESS. (kPa) ______ MIN. PRESS. (kPa) ______
36	○ XENON (Xe)	○ COOLANT COMPOSITION OR ANALYSIS ______
37	○ NITROGEN DIOXIDE (NO_2)	☐ EXCHANGER MFR ______
38	**PARTICULATE CONTAMINANTS IN AIR** (5.6.1.9.2): (kg/Nm^3/hr)	☐ MODEL ______ Δ P ______ mm H_2O
39	○ SEA WATER ______	
40	○ COASTAL WATER ______	**REMARKS:** ______
41	○ ROADS WITH HEAVY TRAFFIC ______	______
42	○ DRY LAKE BED ______	______
43	○ NEARBY COOLING TOWER ______	______
44	○ PERTROCHEMICAL INDUSTRY ______	______
45	○ FOSSIL FIRED POWER PLANT ______	______
46	○ GENERAL CHEMICAL INDUSTRY ______	______
47	○ PAPER AND PULP INDUSTRY ______	______
48	○ CEMENT PRODUCTION ______	______
49	○ QUARRIES ______	______
50	○ AGRICULTURAL ACTIVITIES ______	______
51	○ PRODUCTION OF FERTILIZERS ______	______
52	○ MINING AND METALLURGICAL ACTIVITIES	

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COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **S I UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER

EXHAUST SYSTEM

- ○ EXHAUST HEAT RECOVERY SYSTEM (5.6.1.5) ______
- ○ RELIEF VALVE (5.6.1.6) ○ DIVERSION VALVE (5.6.1.6)
- ☐ ATMOSPHERIC RELIEF DEVICE
- TYPE ______ MFR ______ LOCATION ______
- ☐ EXPANSION JOINT MFR ______ TYPE ______
- ☐ HEAT RECOVERY DEVICE TYPE ______
- ☐ MFR ______ Δ P ______ mm H_2O
- ☐ STEAM GEN: PRESS ______ MPag TEMP ______ °C
- RATE ______ kg/hr
- ○ EXHAUST SILENCER PLATE ELEMENT MATERIAL (5.6.3.1.3)
- ______
- ○ EXHAUST SILENCER EXIT STACK SUPPORT REQ'MTS (5.6.3.1.5)
- ______
- ☐ SILENCER ______ Δ P ______ mm H_2O
- ☐ DUCTING GAUGE / MATERIAL ______ / ______
- ○ EMISSIONS SAMPLING SYSTEM (5.6.3.2.4) ______
- ○ EMISSION CONTROL SYSTEM ______
- ○ EXTENT OF FURNISHED INSULATION (SEE SKETCH) (5.7.1.2)
- ○ EXHAUST STACK MTL. ______
- ☐ MANOMETER MFR ______
- MODEL ______ RANGE ______ mm H_2O
- ☐ SYSTEM SITE RATED PRESS. DROP ______ mm H_2O

ATMOSPHERIC EMISSIONS

- ○ EMISSION SUPPRESSION SYSTEM REQUIRED (5.8.7.1)
- ○ NO_x REQUIREMENTS (5.8.7.2) ______
- ☐ NO_x EMITTED ______

EMISSIONS REDUCTION METHOD (IF REQUIRED)(5.8.7.2)

- ☐ WATER INJECTION (5.8.7.4) ☐ SCR
- ☐ STEAM (5.8.7.4) ○ DRY COMBUSTOR
- ○ OTHER ______
- ○ SO_x REQUIREMENTS ______
- ○ SULFUR CONTENT OF FUEL ______
- SO_x EMITTED (BASED ON STATED SULFUR CONTENT)
- ______
- ○ CO REQUIREMENTS
- ☐ CO / CO_2 EMITTED ______
- ○ PARTICULATE REQUIREMENTS ______
- ☐ PARTICULATE EMITTED ______
- ○ UNBURNED HC REQUIREMENTS ______
- ☐ UNBURNED HC EMITTED ______

APPLICABLE EMISSION CODES OR REGULATIONS

- ○ EPA - TITLE 40 - CFR ○ OTHERS ______

EMISSION LEVEL (5.8.7.3)

- ○ INSTANTANEOUS (PPMV) ○ ANNUAL RATE (tons/yr)
- ○ PROVIDE EMISSIONS WITH & WITHOUT SUPPRESSION (5.8.7.4.1)

FIRE PROTECTION (5.7.3)

- ○ DESIGN STANDARDS (5.7.3.1):
  - ○ NFPA ______ ○ ISO ______

FIRE EXTINGUISHING SYSTEM (5.7.3.1.1 & 5.7.3.1.2):

- ○ NFPA 2001 CLEAN AGENT
- ○ NFPA 750 WATER MIST
- ○ NFPA 12 CARBON DIOXIDE
- ○ ISO 14520 CLEAN AGENT
- ○ ISO 6183 CARBON DIOXIDE

FIRE DETECTION SYSTEM (5.7.3.3):

- ○ NFPA 72E
- ○ ISO 13387-7

GAS DETECTION SYSTEM (5.7.3.4)

- ○ NFPA 72E
- ○ IEC 61779-1

REMARKS: ______

ACOUSTICAL TREATMENT (5.7.4)

- ○ SPECIAL FAR FIELD RESTRICTIONS (5.7.4.2) ______

REMARKS: ______

ENCLOSURES (5.7.5)

- ○ ENCLOSURE REQUIRED, SPECIFY DETAILS (5.7.5.1):

REMARKS: ______

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	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5 th)	REVISION ______ DATE ______
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S I UNITS	

INSPECTION AND TESTING; CONTROLS AND INSTRUMENTATION

SHOP INSPECTION AND TESTS: (6.1.1)	REQ	WIT	OBS
SHOP INSPECTION (6.1.2)	○		
CLEANLINESS (6.2.3.1)	○	○	
HYDROSTATIC (6.3.2)	○	○	○
PNEUMATIC (6.3.3)	○	○	○
MECHANICAL RUN (6.3.4)	○	○	○
AUXILIARY SYSTEMS (6.3.4.1.6) SPECIFY	○	○	○
☐ CONTRACT CPLG ☐ IDLING ADAPTOR(S)			
VIB. PROBES ☐ CONTRACT ☐ SHOP			
VIBRATION PLOTS (6.3.4.3.4)	○		
TAPE RECORD VIB DATA (6.3.4.3.6)	○		
SPARE ROTOR (6.3.4.4.2)	○	○	○
PERFORMANCE TEST (6.3.5.1)	○	○	○
COMPLETE UNIT TEST (6.3.5.2)	○	○	○
PACKAGE TEST (6.3.5.2.1)	○	○	○
TORSIONAL VIBRATION (6.3.5.2.2)	○	○	○
LOAD GEAR TEST (6.3.5.3)	○	○	○
SOUND LEVEL TEST (6.3.5.4)	○	○	○
ROTOR OVERSPEED (6.3.5.5)	○	○	○
AUXILIARY EQUIPMENT (6.3.5.6)	○	○	○
VENTILATION SYSTEM VALIDATION (6.3.5.7)	○	○	○
ENCLOSURE LEAK TEST (6.3.5.8)	○	○	○
POST TEST INSPECTION (6.3.5.9)	○	○	○
HYDRAULIC COUPLING INSP (6.3.5.10)	○	○	○
GOVERNOR RESPONSE TEST (6.3.5.11)	○	○	○
SPARE PARTS (6.3.5.12)	○	○	○
FIRE PROTECTION (6.3.5.13)	○	○	○
UNIT CONTROL PANEL F.A.T.	○	○	○
OTHER (6.3.5.14)	○	○	○
GT FIELD PERFORMANCE TEST (6.3.6)	○	○	○
FIT UP & ASSEMBLY OF COMPONENTS (6.4.9)	○	○	○

CONTROL SYSTEMS

TYPE (5.4.1.8):

○ MECH ○ PNEU ○ HYDRAULIC ○ ELECTRIC ○ ELECTRONIC

○ MICROPROCESSOR BASED ○ COMBINED

○ MONITORS PER API 670: ○ 5.4.7.5 ○ 5.4.7.8.2 ○ 5.4.7.8.4

○ SIGNAL SOURCE ______

○ SENSITIVITY ______ ○ RANGE ______ TO ______

○ TIME OF AC OUTAGE PROTECTION (5.4.1.9) ______ MINUTES

CONTROL CONSOLES (5.4.5.1.1)

○ ON-SKID ○ OFF SKID LOCAL ○ OFF SKID REMOTE

WEATHER PROTECTION REQUIRED ○ YES ○ NO

☐ HUMAN MACHINE INTERFACE ☐ KEYBOARD

STARTING SYSTEM (5.4.2.1)

○ MANUAL ○ SEMI-AUTOMATIC ○ AUTOMATIC

☐ PURGE (5.4.2.2) ______ MINUTES

○ SEPARATE SHUTDOWN VALVE TEST DURING OPERATION

MATERIALS INSPECTION REQUIREMENTS (6.2.1.3)

○ ALTERNATE INSPECTION PROCEDURES (6.2.2.1.1) SPECIFY

○ SPECIAL CHARPY TESTING (4.10.5.3) ______

○ RADIOGRAPHY REQUIRED FOR ______

○ MAGNETIC PARTICLE REQUIRED FOR ______

○ LIQUID PENETRANT REQUIRED FOR ______

○ ULTRASONIC REQUIRED FOR ______

○ QUALITY CONTROL OF INACCESSIBLE WELDS (4.10.4.6.2)

○ 100% INSPECTION OF WELDS (4.10.4.7.1)

○ INSPECTION PRIOR TO CLOSING OPENINGS (6.2.3.3)

○ WELDING HARDNESS TESTING (6.2.3.4)

○ POSITIVE MATERIAL IDENTIFICATION (4.10.1.14.1) ATTACH LIST

○ ADDITIONAL COMPONENTS FOR PMI (4.10.1.14.2) ATTACH LIST

MISCELLANEOUS INSPECTION AND TESTING:

○ SITE TEST OF GT AND DRIVEN EQUIPMENT (4.1.17)

○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION [4.1.18 a)]

○ OBSERVE PARTING OF FLANGES [4.1.18 b)]

○ CHECK ALIGNMENT AT OPERATING TEMPERATURE [4.1.18 c)]

☐ WITNESS INITIAL ALIGNMENT CHECK [4.1.18 d)]

○ FINAL ASSEMBLY CLEARANCES [6.2.1.1 d)] AT GT VENDOR SHOP

SPECIALIZED INSTRUMENTS AND CONTROLS

TACHOMETERS: (5.4.7.2.2)

TYPE ○ ELECTRICAL ○ ELECTRONIC

○ ANALOG ○ DIGITAL

○ MANUFACTURER ______

○ GLYCERIN-FILLED PRESSURE GAUGES (5.4.7.6)

CONTROL WIRING (5.4.5.3.2): ○ ARMORED ○ METAL CONDUIT

SWITCHES: (5.4.4.8.2) CIRCUIT SHALL:

○ ENERGIZE ○ DEENERGIZE TO ALARM

○ ENERGIZE ○ DEENERGIZE TO SHUTDOWN

INSTRUMENT / ELECTRICAL ENCLOSURES

○ EXPLOSION PROOF ○ WEATHER PROOF

CONTROL / INSTRUMENT WIRING (5.4.5.3.2) ○ ARM. CABLE ○ CONDUIT

CONTROL SYSTEM DETAILS:

○ ALARM & SHUTDOWN ARRANGEMENTS (5.4.4.8)

○ ALARM & SHUTDOWN SWITCHES (5.4.4.8.1)

○ FIRST-OUT ANNUNCIATOR REQ'D (5.4.4.8.5)

○ PURGE FIRST-OUT ANNUNCIATOR REQ'D [5.4.4.8.5 b)]

○ SHUT OFF VALVES FOR SHUT DOWN SENSORS (5.4.4.9)

○ SHUTDOWN DEVICE ISOLATION LOCKOUT (5.4.4.10)

LOAD CONTROL - GOVERNOR (5.4.3)

○ MFR'S STD. ○ OTHER ○ MAKE ______ ○ MODEL ______

○ CONSTANT SPEED ○ VARIABLE SPEED

○ ISOCHRONOUS ○ DROOP

REMOTE SHUTDOWN SIGNAL, SPECIFY TYPE: ______

○ CONTROL SIGNAL RANGE (5.4.3.3) ______

MANUAL SPEED CHANGER, r/min ______ MAX. ______ MIN.

○ MAINTAIN TURBINE SPEED UPON FAILURE OF CONTROL SIGNAL OR ACTUATOR

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	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **S I UNITS**	REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

LUBRICATION, WEIGHTS & VENDOR DATA

☐ **WEIGHTS**	DRY INSTALLED (kg)	SHIPPING (kg)	DIMENSIONS LxWxH (m)
GAS GENERATOR			
POWER TURBINE			
GT ENCLOSURE			
INLET FILTER HOUSE			
INLET AIR DUCTING			
VENT DUCTING			
EXHAUST DUCTING			
EXHAUST STACK			
MIN OIL CONSOLE			
SYN OIL CONSOLE			
MIN OIL SEPARATOR			
SYN OIL SEPARATOR			
MIN OIL AIR COOLER			
SYN OIL AIR COOLER			
HYD START SKID			
CO_2 CYLINDER SKID			
WATER WASH SKID			
TOTAL PACKAGE WT			
MAX ERECTION WT		ITEM	
MAX MAINT WT		ITEM	

LUBRICATION SYSTEMS (4.9)

○ API 614 DATASHEETS ______

☐ **MINERAL** LUBE SYSTEM (4.9.5) ○ OIL VISCOSITY ______

COMMON TO ▢ GAS GENERATOR or SINGLE SHAFT GT
▢ FREE POWER TURBINE ▢ LOAD GEAR
▢ DRIVEN EQUIPMENT ▢ AUXILIARIES

○ **SYNTHETIC** LUBE OIL SYSTEM (4.9.2) ☐

☐ LUBE SPECIFICATION ______

COMMON TO ▢ GAS GENERATOR ▢ POWER TURBINE
▢ LOAD GEAR ▢ DRIVEN EQUIPMENT
▢ AUXILIARIES ▢ ______

○ OIL DEBRIS MONITORING ______

☐ **OIL REQUIREMENTS**	FLOW (m^3/hr)	PRESSURE (barG)	HEAT LOAD (kW)
GAS GENERATOR			
POWER TURBINE			
HYD START SYSTEM			

MINERAL OIL RESERVOIR CAPACITY ______ liters

SYNTHETIC OIL RESERVOIR CAPACITY ______ liters

HYDRAULIC OIL RESERVOIR CAPACITY ______ liters

HYDRAULIC OIL SPECIFICATION

MOUNTING ARRANGEMENT: ○ CONSOLE ○ COLUMN ○ BASEPLATE

VENDOR'S DATA:

○ COORDINATION MEETING SITE (7.1.3) ______

○ SPARE PARTS OPTIMIZATION ANALYSIS [(7.2.3 v)]

○ FAILURE MODES AND EFFECTS ANALYSIS [7.2.3 w)]

○ LIFE CYCLE COST ANALYSIS [7.2.3 x)]

PERFORMANCE CURVES (7.2.4)

- ○ SPEED-TORQUE CURVE OF OUTPUT SHAFT [7.2.4 a]
- ○ INCREMENTAL POWER FOR STEAM/WATER [7.2.4 b)]
- ○ EFFECTS OF AMB. COND. ON EXHAUST FLOW [7.2.4 c)]
- ○ RUN DOWN CURVES [7.2.4 d)]
- ○ NO_X AND CO_2 EMISSIONS [7.2.4 e)]
- ○ IMPACT OF ANTI-ICING SYSTEM [7.2.4 f)]

○ PROGRESS REPORTS (7.3.4)

○ TECHNICAL DATA MANUAL (7.3.6.4)

REMARKS:

REMARKS:

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	JOB NO. ______ ITEM NO. ______
	PURCHASE ORDER NO. ______
	SPECIFICATION NO. ______
COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **U.S. CUSTOMARY UNITS**	REVISION NO. ______ DATE ______
	PAGE ______ OF ______ BY ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS-BUILT

FOR ______ UNIT ______

SITE ______ SERIAL NUMBER ______

SERVICE ______ NUMBER REQUIRED ______

○ CONTINUOUS ○ INTERMITTENT ○ STANDBY DRIVEN EQUIPMENT ______

MANUFACTURER ______ MODEL ______ ISO RATING (3.21) ______ hp @ ______ r/min

NOTE: INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER ◙ BY MFR IF NOT BY PURCHASER

GENERAL

CYCLE: ○ REGEN ○ SIMPLE ○ EXHAUST HEAT RECOVERY TYPE: ______ ◙ SINGLE SHAFT ◙ MULTI SHAFT

DRIVEN EQUIPMENT POWER: NORMAL SHAFT ______ hp @ ______ r/min RATED SHAFT ______ hp @ ______ r/min

GAS TURBINE DRIVER OUTPUT SHAFT SPEED RANGE (4.1.5) ○ MIN ______ r/min ○ MAX ______ r/min

○ DESIRED MINIMUM SITE POWER ______ hp ______ r/min ○ ______

OPERATION ○ ATTENDED ○ UNATTENDED □ POTENTIAL MAXIMUM POWER (3.41) ______ hp

NOTE: All Datasheets References to GG = Gas Generator, SS = Single Shaft, and PT = Power Turbine

PERFORMANCE

GAS TURBINE INCLUDING ALL LOSSES

○ INLET LOSS ______ in. H_2O EXHAUST LOSS ______ in. H_2O

○ INLET AIR CHILLER DESIGN RATING ______

		SITE RATED (3.52)	NORMAL DUTY (3.32)	SITE MAX TEMP	SITE MIN TEMP
○ DRY BULB TEMP (AMB)	°F				
○ TURBINE INLET AIR CHILLED (Y/N)					
○ TURBINE INLET TEMP	°F				
○ RELATIVE HUMIDITY (AMB)	%				
○ BAROMETRIC PRESS	psia				
□ GT OUTPUT SHAFT POWER	hp				
□ GG OUTPUT SHAFT SPEED	r/min				
□ PT OUTPUT SHAFT SPEED	r/min				
□ LHV HEAT RATE	BTU/hp-hr				
□ LHV EFFICIENCY	%				
□ FIRING TEMPERATURE	°F				
□ AIR FLOW	lb/s				
□ GG EXHAUST TEMP	°F				
□ PT EXHAUST FLOW	lb/s				
□ PT EXHAUST TEMP	°F				
□ FUEL FLOWRATE	lb/hr				
○ CERTIFIED POINT (3.32)					

INCLUDING ○ STEAM ○ WATER EFFECTS FOR

◙ EMISSION CONTROL ◙ AUGMENTATION (4.1.9)

□ STEAM FLOW, lb/hr ______ ______ ______

□ WATER FLOW, gal/min

APPLICABLE SPECIFICATIONS:

○ API 616 GT FOR THE PETROLEUM, CHEMICAL, & GAS INDUSTRY SERVICES

○ GOVERNING SPECIFICATION (IF DIFFERENT) ______

○ VENDOR HAVING UNIT RESPONSIBILITY (4.1.2) ______

○ OTHER ______

SHIPMENT: (6.4)

○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED

○ OUTDOOR STORAGE MORE THAN 6 MONTHS (6.4.1)

SPARE ROTOR ASSEMBLY PACKAGED FOR (6.4.3.10)

○ DOMESTIC SHIPMENT ○ EXPORT SHIPMENT

LOCATION (4.1.19)

○ INDOOR ○ OUTDOOR ○ GRADE

○ HEATED ○ UNDER ROOF ○ MEZZANINE

○ UNHEATED ○ PARTIAL SIDES ○ OTHER ______

○ AMBIENT TEMPERATURE RANGE (°F) (5.1.2.1)

MINIMUM ______ NORMAL ______ MAXIMUM ______

○ EXTREME AMBIENT TEMPERATURES (°F) (5.1.2.1)

MINIMUM ______ MAXIMUM ______

○ SEISMIC DESIGN ZONE ______

○ WIND DESIGN VELOCITY ft/s ______

○ ELEVATION ______ ft ○ PRECIPITATION ______

ELECTRICAL AREA CLASSIFICATION(4.1.14)

○ UNCLASSIFIED ○ HAZARDOUS

APPLICABLE CODE: (5.4.1.5.3) ○ NEC 500 ○ NEC 505 ○ IEC

ZONE ______ GROUP: ______ TEMP. CODE: ______

AREA CLASSIFICATION ○ ______

AREA CLASSIFICATION ENCLOSURE INTERIOR ○ ______

○ THIRD-PARTY CERTIFICATION REQUIRED

○ WINTERIZATION REQD ○ TROPICALIZATION REQD (5.4.6.6)

UNUSUAL CONDITIONS:

○ DUST ○ FUMES

○ NORMAL / MAX DUST LOADING lb/SCFM ______

○ SNOW LOAD lb/ft^2 ______

NOISE LIMIT REQUIREMENTS: (4.1.10)

○ GAS TURBINE ENCLOSURE ______ dBA ○ PRESSURE ○ POWER

○ INLET SYSTEM ______ dBA ○ PRESSURE ○ POWER

○ EXHAUST SYSTEM ______ dBA ○ PRESSURE ○ POWER

PAINTING:

○ MANUFACTURER'S STANDARD

○ MANUFACTURER'S STANDRAD FOR MARINE ENVIRONMENT

MISCELLANEOUS:

○ BOLT THREADING (4.2.7.1)

THREADED OPENINGS & BOSSES (4.4.3.4): ○ ISO ○ ASME

ISO 7-1:1994 THREADS (4.4.3.4): ○ TAPERED ○ STRAIGHT

IRON FLANGES (4.4.5.1): ○ ISO ○ ASME

MACHINED & STUDDED CONNECTIONS (4.4.6): ○ ISO ○ ASME

○ PURCHASER REVIEW OF CAMPBELL / GOODMAN DIAGRAM (4.5.3.4)

○ LOW TEMPERATURE MATERIALS REQ'D (4.10.5.1)

COMMENTS:

1

COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

FUEL SYSTEM (5.8)

TYPE ○ GAS (5.8.2) ○ LIQUID (5.8.3) ○ DUAL (5.8.5.1)

DUAL SYSTEM REQMTS (5.8.5.1) ○ GAS/GAS ○ LIQUID/GAS ○ LIQUID/LIQUID

○ FUEL GAS COMPRESSION SYSTEM REQ'D [5.8.1.2.1.3 c)] ○ MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER ______ seconds

GAS FUELS (5.8.2)

	M.W.	NORMAL	START-UP	ALTERNATE
○ HC DEW PT,ºF @ psia				
○ FUEL ANALYSIS - MOL % (5.8.2.1)				
COMPOSITION:	M.W.	NORMAL	START-UP	ALTERNATE
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			
N-BUTANE	58			
I-PENTANE	72			
N-PENTANE	72			
HEXANE PLUS				
TOTAL	%	100.00	100.00	100.00
AVG. MOL. WT.				
○ LHV (5.8.2.4.1)	BTU/SCF			
☐ REQ'D FUEL TEMP	°F			
☐ WOBBE INDEX REQ'D				
☐ FUEL PRESSURE REQUIRED	psig			
CONTAMINENTS (5.8.2.2.1)				
○ TAR	PPM			
○ CARBON BLACK	PPM			
○ COKE	PPM			
○ SOLIDS	PPM			
○ NAPHTHALENE	PPM			
○ GAS HYDRATES	PPM			
○ ______	PPM			
CORROSIVE AGENTS (5.8.2.3.1)	PPM			
○ HYD. SULPHIDE	PPM			
○ SULPHUR DIOXIDE	PPM			
○ SULPHUR TRIOXIDE	PPM			
○ TOTAL SULPHUR	PPM			
○ ALKALI METALS	PPM			
○ CHLORIDES	PPM			

GAS FUEL SYSTEM AND COMPONENTS

○ FUEL GAS BYPASS & VENT [5.8.1.2.1.3 d)]

☐ MANUAL ISOLATION VALVE MFR (5.8.1.2.2) ______

○ SECONDARY VENT VALVE ______

☐ PRIMARY FAST SHUT OFF MFR (5.8.1.2.4) ______

☐ LEAK TIGHT SHUT OFF MFR (5.8.1.2.4) ______

☐ EXTERNAL SHUT OFF VALVE MFR (5.8.1.2.5) ______

○ DUAL Y-TYPE STRAINERS REQ'D (5.8.1.2.6.2)

HEATER REQD (5.8.2.7) ☐ YES ☐ NO

☐ MANUFACTURER ______

☐ REQ'D FUEL TEMP ABOVE DEW POINT ______

○ COALESCING FILTER (5.8.2.2.3)

☐ MANUFACTURER ______

○ RATE OF CHANGE OF LHV (5.8.2.4.2) ______

FUEL ANALYZER EQUIPMENT:

○ CALORIMETER

○ GAS CHROMATOGRAPH

○ WOBBE METER

○ SUPPLY FILTRATION (5.8.1.2.6) ______

PIPING, TUBING & DESIGN DETAILS

○ PRESENCE OF HYDROGEN SULFIDE ______

○ NACE MATERIAL STANDARDS (4.10.1.9) ______

○ ANSI FLANGE RATING ______

○ PIPING / TUBING GRADE ______

○ TUBE FITTING MANUFACTURER ______

○ MAXIMUM VENT BACKPRESSURE (5.8.1.2.8) ______ psig

"SHIP LOOSE" FUEL GAS SYSTEM COMPONENTS

☐ Y-TYPE STRAINERS ______

☐ DUPLEX FUEL GAS FILTERS ______

☐ PIPING ______

☐ HEATERS ______

☐ GAS ANALYSIS EQUIPMENT ______

REMARKS: ______

COMBUSTION GAS TURBINE (API 616-5th) DATASHEET U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ___ OF ___ BY ______

FUEL SYSTEM (5.8)

TYPE ○ GAS (5.8.2) ○ LIQUID (5.8.3) ○ DUAL (5.8.5.1)

DUAL SYSTEM REQMTS (5.8.5.1) ○ GAS/GAS ○ LIQUID/GAS ○ LIQUID/LIQUID

○ MAXIMUM TIME ALLOWED TO COMPLETE TRANSFER ______ seconds

LIQUID FUEL SYSTEM (5.8.3)

FUEL GRADES (5.8.4.3):

- ○ ASTM D2880 GRADE (5.8.4.3.1)
  - ○ GRADE 0-GT
  - ○ GRADE 1-GT
  - ○ GRADE 2-GT
  - ○ GRADE 3-GT
  - ○ GRADE 4-GT
- ○ ASTM D1655 (5.8.4.3.2)
  - ○ JET A OR JET A-1
  - ○ JET B
- ○ OTHER, INDICATE ANALYSIS (5.8.4.3.3)

☐ ISOLATION VALVE LOCATION (5.8.3.2)

☐ FLOW CONTROL DEVICE (5.8.3.3)

☐ SHUT-OFF VALVE (5.8.3.4)

☐ SPILL VALVE (5.8.3.4)

☐ DRAIN VALVE (5.8.3.6)

☐ FILTER / STRAINER (5.8.3.7)

☐ VALVE PROVING & POSITION MONITORING (5.8.3.8)

☐ THERMAL RELIEF VALVES (5.8.3.9)

☐ MULTI FUEL SYSTEMS (5.8.3.10)

☐ FUEL PURGING (5.8.3.11)

☐ FUEL DRAINAGE (5.8.3.12)

☐ OTHER SYSTEM COMPONENTS (5.8.3.13)

○ FUEL TRANSFER EQUIP REQUIRED (5.8.3.15)

FUEL PUMP SYSTEM DETAILS

- ○ FUEL PUMP REQUIRED
  - ○ RV AT PUMP DISCHARGE (YES/NO)
  - ○ RV SET POINT bar
  - ○ PUMP RATED CAPACITY l/min

PIPING, TUBING & DESIGN DETAILS

- ○ PRESENCE OF HYDROGEN SULFIDE
- ○ NACE MATERIAL STANDARDS (4.10.1.9)
- ○ ANSI FLANGE RATING
- ○ PIPING / TUBING GRADE
- ○ TUBE FITTING MANUFACTURER

LIQUID FUELS (5.8.4)

LIQUID FUEL TREATMENT REQUIRED ☐ YES ☐ NO

TREATMENT SYSTEM BY ○ VENDOR ○ OTHER

HEATER REQUIRED (5.8.3.14) ☐ YES ☐ NO

☐ LIQUID FUEL PRESS REQUIRED, MAX/MIN, psig

☐ **FUEL ANALYSIS DATA** (5.8.4.3)

PROPERTY	ASTM METHOD	○ MEASURED VALUE
VISCOSITY, cSt @ 38°F	D-445	○
DISTILLATION DATA	D-86	
10% / 50% / 90% RECOVERY, °F MAX		○
END POINT, °F MAX		○
SULFUR CONTENT %WEIGHT, MAX. (SELECT APPL. METHOD)		
BOMB METHOD	D-129	○
LAMP METHOD	D-1266	○
HIGH-TEMP METHOD	D-1552	○
CARBON RESIDUE (ON 10% BOTTOMS) % WT. MAX.		○
CONRADSON	D-189	○
RAMSBOTTOM	D-524	○
COPPER STRIP CORROSION PLATE	D-130	
3 HOURS AT 100°F MAXIMUM		○
AROMATIC CONTENT % WT	D-5186	○
ASH CONTENT	D-482	○
SPECIFIC GRAVITY, lb/ft^3 @ 15°F	D-4052	○
FLASH POINT, °F	D-56	○
CLOUD POINT, °F	D-2500	○
POUR POINT, °F	D-97	
WATER	D-95	○
PARTICULATES, MG/100ML	D-2276	○
TRACE METALS (ATOMIC ABSORPTION PREFERRED)	D-3605	○
SODIUM		○
POTASSIUM		○
VANADIUM		○
CALCIUM		○
LEAD		○
OTHER METALS		○
LOWER HEATING VALUE, BTU/lb	D-2382	○
REID VAPOR PRESSURE, psia	D-323	○
OLEFIN CONTENT, % VOL	D-1319	○

REMARKS:

3

COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ____ ITEM NO. ____ REVISION ____ DATE ____ PAGE ____ OF ____ BY ____

CONSTRUCTION FEATURES

○ SPEEDS:

MAX. CONT. ____ r/min TRIP ____ r/min

☐ LATERAL CRITICAL SPEEDS (DAMPED)

FIRST CRITICAL		r/min		r/min
SECOND CRITICAL		r/min		r/min
THIRD CRITICAL		r/min		r/min
FOURTH CRITICAL		r/min		MODE

☐ PROTOTYPE OR MODIFIED ROTOR SUPPORT (4.7.1)

○ TRAIN LATERAL ANALYSIS REQUIRED (4.7.2.6)

○ TRAIN TORSIONAL ANALYSIS REQUIRED (4.7.3.1)

☐ TORSIONAL CRITICAL SPEEDS:

FIRST CRITICAL		r/min
SECOND CRITICAL		r/min
THIRD CRITICAL		r/min
FOURTH CRITICAL		r/min

VIBRATION: (4.7.5.2.1) (4.7.5.3.1) [7.2.3 o)]:

☐ ACCEPTANCE LIMITS: SHAFT ____ µm P-P

CASE ____ in./s

☐ ROTATION, VIEWED FROM DRIVE END ☐ CW ☐ CCW

AIR COMPRESSOR:

STAGES ____ MAXIMUM TIP SPEED ____ ft/s

TYPE ____ PRESSURE RATIO ____

CASING SPLIT (4.2.3) ☐ AXIAL ☐ RADIAL

ROTOR ☐ SOLID ☐ BUILT UP

TURBINE:

STAGES ____ MAX. TIP SPEED ____ ft/s

CASING SPLIT (4.2.3) ☐ AXIAL ☐ RADIAL

ROTOR ☐ SOLID ☐ BUILT UP

COMBUSTORS: (4.3.2) ○ DRY LOW EMISSIONS REQUIRED

☐ SINGLE ☐ MULTIPLE, NUMBER ____

☐ GAS ☐ LIQUID ☐ DUAL FUEL

☐ FUEL NOZZLES PER COMBUSTOR ____

☐ CONFIGURATION ____

☐ MAXIMUM ALLOWABLE TEMP. VARIATION ____ °F

APPLICABLE PLANE ____

☐ WOBBE INDEX REQD (4.3.7) ☐ MAX MIN

COMBUSTION SYSTEM DETAILS:

REMARKS:

MATERIALS OF CONSTRUCTION (4.10)

COMPRESSOR ROTOR BLADES ____

COMPRESSOR STATOR VANES ____

COMPRESSOR BLADE/VANE COATING ____

GG SHAFT ____ PT SHAFT ____

GG COMPRESSOR CASING ____

GG HPT CASING ____ PT CASING ____

COMBUSTOR LINER ____

COMBUSTOR HEAT SHIELD ____

GG HP TURBINE (HPT) and POWER TURBINE (PT):

TURBINE STAGE	NOZZLES	BLADES	DISKS or SHROUDS
HPT-S1			
HPT-S2			
PT-S1			
PT-S2			

BALANCING:

○ LOW SPEED BALANCING (4.7.4.2)

○ HIGH SPEED BALANCING (4.7.4.3.1)

ACCEPTANCE CRITERIA (4.7.4.3.2)

○ GRADE 2.5 ○ ISO 11342 ○ 1.0 in./s

○ LOW SPEED RESIDUAL BALANCE CHECK (4.7.4.3.4)

MAINTENANCE INTERVALS, HOURS / DURATION, HOURS

☐ BORESCOPE INSP. ____ / ____

☐ HOT SECTION OVERHAUL ____ / ____

☐ MAJOR OVERHAULS ____ / ____

REMARKS:

FOR MULTIPLE SHAFT TURBINES PROVIDE DATA FOR EACH SHAFT

4

COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

GAS GENERATOR - CONSTRUCTION FEATURES

BEARINGS AND BEARING HOUSINGS (4.8)

RADIAL BEARINGS		DE	NDE
		BRG No.	BRG No.
☐ TYPE			
☐ MANUFACTURER			
☐ SIZE	in.		
☐ RATED SHAFT SPEED	r/min		
☐ RADIAL LOAD	lbf		
☐ BEARING 'C' RATING	lbf		
☐ L-10 BEARING LIFE	hr		
☐ INNER / OUTER RACE MAT'L			
☐ ROLLING ELEMENT MAT'L			
☐ CAGE MATERIAL			

RADIAL / THRUST		RADIAL	THRUST
		BRG No.	BRG No.
☐ TYPE			
☐ MANUFACTURER			
☐ SIZE	in.		
☐ RATED SHAFT SPEED	r/min		
☐ RADIAL/THRUST LOAD	lbf		
☐ BEARING 'C' RATING	lbf		
☐ L-10 BEARING LIFE	hr		
☐ INNER / OUTER RACE MAT'L			
☐ ROLLING ELEMENT MAT'L			
☐ CAGE MATERIAL			

☐ BEARING SPAN (BETWEEN BRG No.X and No.Y) ______ in.

☐ OTHER

LUBRICATION: ☐ FLOODED ☐ DIRECTED

THRUST COLLAR: ☐ INTEGRAL ☐ REPLACEABLE

BEARING TEMPERATURE SENSORS (4.8.5.5)

○ SEE ATTACHED API-670 DATASHEETS
○ THERMOCOUPLES
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ RESISTANCE TEMPERATURE DETECTORS ______
○ RESISTANCE MATL ______ ○ ______ OHMS
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ LOCATION-JOURNAL BEARING:
NUMBER ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ LOCATION-THRUST BEARING
NO. (ACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
NO.(INACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ MONITOR SUPPLIED BY (5.4.7.5) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RANGE ______ ☐ ALARM SET @ ____ °F
○ SHTDWN ☐ SET @ ____ °F ☐ TIME DELAY ____ seconds

CASING AND / OR ROLLING ELEMENT VIBRATION TRANSDUCERS (5.4.7.8)

○ SEE ATTACHED API-670 DATASHEETS
○ CASING VIBRATION (5.4.7.8.3) ○ ROLLING ELEMENT VIB. (5.4.7.8.5)
○ MFR ______ ○ MODEL ______
○ LOCATION ______ ○ NUMBER ______
○ MONITOR SUPPLIED BY (5.4.7.8.4) ______
○ MONITOR SUPPLIED BY (5.4.7.8.6) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ in./s
○ SHTDWN ☐ SET @ ____ mm/s ☐ TIME DELAY ____ seconds

PROXIMITY PROBES (4.8.5.3)

RADIAL SHAFT VIBRATION PROBES

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______
○ NO. AT EACH SHAFT BRG ______ TOTAL NO. ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ ____ mils ☐ TIME DELAY ____ seconds

AXIAL POSITION PROBES (4.8.5.3)

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______ ○ NO. REQUIRED ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ mils ☐ TIME DELAY ____ seconds

REMARKS:

	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

POWER TURBINE - CONSTRUCTION FEATURES

BEARINGS AND BEARING HOUSINGS (4.8)

RADIAL		DE	NDE	THRUST		ACTIVE	INACTIVE
		BRG No.	BRG No.			DE/NDE	DE/NDE
☐ TYPE				☐ TYPE			
☐ MANUFACTURER				☐ MANUFACTURER			
☐ SHAFT DIAMETER	in.			☐ SHAFT DIAMETER	in.		
☐ BEARING LENGTH	in.			☐ BEARING SIZE	in.		
☐ AREA,	$in.^2$			☐ AREA	$in.^2$		
☐ UNIT LOAD (ACT/ALLOW)	$lbf/in.^2$			☐ UNIT LOAD (ACT/ALLOW)	$lbf/in.^2$		
☐ BASE MATERIAL				☐ BASE MATERIAL			
☐ BABBITT THICKNESS	in.			☐ BABBITT THICKNESS	in.		
☐ NO. PADS				☐ NO. PADS			
☐ LOAD: BETWEEN/ON PAD				PIVOT: CENTER/OFFSET	%		
☐ PIVOT: CENTER/OFFSET	%						

☐ BEARING SPAN (BETWEEN BRG No.X and No.Y) ______ in.

☐ DAMPER BEARING

LUBRICATION: ☐ FLOODED ☐ DIRECTED

THRUST COLLAR: ☐ INTEGRAL ☐ REPLACEABLE ______

BEARING TEMPERATURE SENSORS (4.8.5.5)

○ SEE ATTACHED API-670 DATASHEETS
○ THERMOCOUPLES
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ RESISTANCE TEMPERATURE DETECTORS ______
○ RESISTANCE MAT'L ______ ○ ______ OHMS
○ SELECTOR SWITCH & IND. BY: ____ PURCH ____ MFR
○ LOCATION-JOURNAL BEARING:
NUMBER ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ LOCATION-THRUST BEARING
NO. (ACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
NO.(INACT) ____ EA PD ____ EVERY OTH PAD ____ PER BRG
OTHER ______
○ MONITOR SUPPLIED BY (5.4.7.5) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ○ MODEL ______
☐ SCALE RANGE ______ ☐ ALARM SET @ ____ °F
○ SHTDWN ☐ SET @ ____ °F ☐ TIME DELAY ____ seconds

CASING AND / OR ROLLING ELLEMENT VIBRATION TRANSDUCERS (5.4.7.8)

○ SEE ATTACHED API-670 DATASHEETS
○ CASING VIBRATION (5.4.7.8.3) ○ ROLLING ELEMENT VIB. (5.4.7.8.5)
○ MFR ______ ○ MODEL ______
○ LOCATION ______ ○ NUMBER ______
○ MONITOR SUPPLIED BY (5.4.7.8.4) ______
○ MONITOR SUPPLIED BY (5.4.7.8.6) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ☐ ______ ○ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ in./s
○ SHTDWN ☐ SET @ ____ in./s ☐ TIME DELAY ____ seconds

PROXIMITY PROBES (4.8.5.3)

RADIAL SHAFT VIBRATION PROBES

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______
○ NO. AT EACH SHAFT BRG ______ TOTAL NO. ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
MFR ______ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ ____ mils ☐ TIME DELAY ____ seconds

AXIAL POSITION PROBES (4.8.5.3)

○ SEE ATTACHED API-670 DATASHEETS
○ TYPE ______ ○ MODEL ______
○ MFR ______ ○ NO. REQUIRED ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ○ MODEL ______
○ MONITOR SUPPLIED BY (5.4.7.8.2) ______
○ LOCATION ______ ENCLOSURE ______
○ MFR ______ ☐ MODEL ______
☐ SCALE RGE ______ ☐ ALARM SET @ ____ µm
○ SHUTDWN ☐ SET @ ____ mils ☐ TIME DELAY ____ seconds

REMARKS: ______

6

COMBUSTION GAS TURBINE (API 616-5 th) DATASHEET U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

UTILITIES

○ **UTILITY CONDITIONS:**	☐ **TOTAL UTILITY CONSUMPTION:**
STEAM: **AUXILIARY DRIVERS** **HEATING**	IAH / COOLING / IAC WATER ____ / ____ / ____ gal/min
INLET MIN ____ psig ____ °F ____ psig ____ °F	STEAM LEVEL ____ psig ____ psig ____ psig
NORM ____ psig ____ °F ____ psig ____ °F	STEAM, NORMAL ____ lb/hr ____ lb/hr ____ lb/hr
MAX ____ psig ____ °F ____ psig ____ °F	STEAM, MAX ____ lb/hr ____ lb/hr ____ lb/hr
EXHST MIN. ____ psig ____ °F ____ psig ____ °F	INSTRUMENT AIR ____ SCFM
NORM ____ psig ____ °F ____ psig ____ °F	NITROGEN ____ SCFM
MAX ____ psig ____ °F ____ psig ____ °F	MOTORS (AUXILIARIES) ____ hp
STARTING **INJECTION**	BATTERY CHARGERS ____ hp
INLET MIN ____ psig ____ °F ____ psig ____ °F	HEATERS ____ hp
NORM ____ psig ____ °F ____ psig ____ °F	**TURBINE AIR EXTRACTION REQUIRED:** (4.1.22)
MAX ____ psig ____ °F ____ psig ____ °F	○ SCFM ____ @ ____ psig
EXHST MIN. ____ psig ____ °F	☐ MAXIMUM PRESSURE AVAILABLE AT MINIMUM SPEED: psig
NORM ____ psig ____ °F	☐ MINIMUM SPEED: ____ r/min
MAX ____ psig ____ °F	☐ DISCHARGE TEMPERATURE ____ °F
	☐ COMPRESSOR EXTRACTION STAGE NUMBER: ____
○ INLET AIR HUMIDIFICATION (IAH) WATER:	
INLET TEMPERATURE ____ °F	○ INSTRUMENT AIR PRESSURE DESIGN, psig ____
DESIGN TEMPERATURE ____ °F	MAX ____ NORMAL ____ MIN ____
NORM PRESS ____ psig	○ NITROGEN PRESSURE DESIGN, psig ____
DESIGN PRESS ____ psig	MAX ____ NORMAL ____ MIN ____
○ COOLING WATER:	
INLET TEMPERATURE ____ °F MAX RETURN ____ °F	**ELECTRICITY:** (5.4.6.1) ○ PILOT LIGHT INDICATORS
DESIGN TEMPERATURE ____ °F	
NORM PRESS ____ psig MIN RETURN ____ psig	
DESIGN PRESS ____ psig MAX ALLOW Δ P ____ Mpa D	
WATER SOURCE ____	
○ INLET AIR CHILLING (IAC) WATER:	**REMARKS:** ____
INLET TEMPERATURE ____ °F MAX RETURN ____ °F	____
DESIGN TEMPERATURE ____ °F	____
NORM PRESS ____ psig MIN RETURN ____ psig	____
DESIGN PRESS psig MAX ALLOW Δ P psig	

	MOTORS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

PURCHASER CONNECTIONS

CONNECTION	○ DESIGN APPROVAL REQUIRED (4.10.4.7.4)	☐ SIZE	☐ FACING and RATING	☐ POSITION (4.4.1)	◙ FLANGED OR STUDDED (4.4.1)	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY ft/s

COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ______	ITEM NO. ______	
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1	**INSTRUMENTS**									
2	**INSTRUMENTATION & INSTALLATION:** (5.4.1.1.)						TRANS-		CONTROL	
3	○ API 614/ISO 10438 ○ ______	INSTRUMENT		INSTRUMENT			MITTERS		ROOM	
4	○ INSTRUMENTATION MOUNTING (5.4.4.7)	TYPE		LOCATION			FURNISHED		RECEIVERS	
5	○ OPTIONAL ALARM & SHUTDOWN POINT (5.4.4.7) SEE ADD. SHEET						BY		FURN BY	
6	**DESCRIPTION**	INDICATING	RECORDING	LOCAL	LOCAL PANEL	CONTROL ROOM	VENDOR	OTHERS	VENDOR	OTHERS
7	**GAS GENERATOR OR SINGLE SHAFT GAS TURBINE**									
8	TACHOMETER(S)	○	○	○	○	○	○	○	○	○
9	Δ P AIR INLET SYSTEM	○	○	○	○	○	○	○	○	○
10	COMPRESSOR DISCHARGE PRESSURE	○	○	○	○	○	○	○	○	○
11	FUEL FILTER Δ P	○	○	○	○	○	○	○	○	○
12	FUEL SUPPLY PRESSURE	○	○	○	○	○	○	○	○	○
13	STARTING GAS SUPPLY PRESSURE	○	○	○	○	○	○	○	○	○
14	STARTING GAS EXHAUST PRESSURE	○	○	○	○	○	○	○	○	○
15	TEMP COMBUSTOR MEASUREMENT (6 PTS MIN) (4.3.2)	○	○	○	○	○	○	○	○	○
16	TEMP GAS TURB CONTROL PLANE (6 PTS MIN)	○	○	○	○	○	○	○	○	○
17	INLET AIR TEMPERATURE	○	○	○	○	○	○	○	○	○
18	TEMPERATURE, GG COMPRESSOR DISCHARGE	○	○	○	○	○	○	○	○	○
19	TEMPERATURE, THRUST BEARING OIL DRAIN	○	○	○	○	○	○	○	○	○
20	TEMPERATURE, EACH BEARING SUMP-ROLLING ELEMENT TYPE)	○	○	○	○	○	○	○	○	○
21	TEMPERATURE, FUEL MANIFOLD	○	○	○	○	○	○	○	○	○
22	TEMPERATURE, LUBE OIL RESERVOIR	○	○	○	○	○	○	○	○	○
23	FIRED HOUR METER	○	○	○	○	○	○	○	○	○
24	A) NUMBER STARTS COUNTER	○	○	○	○	○	○	○	○	○
25	B) START SEQUENCE TIMER	○	○	○	○	○	○	○	○	○
26	LUBE OIL RESERVOIR LEVEL	○	○	○	○	○	○	○	○	○
27	LUBE OIL PUMP PRESSURE INDICATORS (NO.)	○	○	○	○	○	○	○	○	○
28	LUBE OIL COOLER OIL INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
29	LUBE OIL COOLER OIL OUTLET TEMPERATURE	○	○	○	○	○	○	○	○	○
30	LUBE OIL COOLER COOLANT INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
31	LUBE OIL COOLER COOLANT OUTLET TEMPERATURE	○	○	○	○	○	○	○	○	○
32	LUBE OIL FILTER Δ P	○	○	○	○	○	○	○	○	○
33	LUBE OIL PRESSURE EACH LEVEL (NO.)	○	○	○	○	○	○	○	○	○
34	CONTROL OIL PRESSURE	○	○	○	○	○	○	○	○	○
35	SITE FLOW INDICATOR EACH DRAIN (NO.)	○	○	○	○	○	○	○	○	○
36	INLET GUIDE VANE POSITION INDICATOR	○	○	○	○	○	○	○	○	○
37	EXHAUST DUCT DIFFERENTIAL PRESSURE INDICATOR	○	○	○	○	○	○	○	○	○
38	ENCLOSURE COOLING AIR EXHAUST TEMPERATURE	○	○	○	○	○	○	○	○	○
39	**POWER TURBINE**									
40	TACHOMETER(S) (NO.)	○	○	○	○	○	○	○	○	○
41	EXHAUST TEMPERATURE (2 POINTS MIN)	○	○	○	○	○	○	○	○	○
42	JOURNAL BEARING TEMPERATURE	○	○	○	○	○	○	○	○	○
43	THRUST BEARING TEMPERATURE	○	○	○	○	○	○	○	○	○
44	BEARING DRAIN TEMPERATURE	○	○	○	○	○	○	○	○	○
45	SITE FLOW INDICATOR EACH DRAIN (NO.)	○	○	○	○	○	○	○	○	○
46	LUBE OIL INLET PRESSURE	○	○	○	○	○	○	○	○	○
47	LUBE OIL INLET TEMPERATURE	○	○	○	○	○	○	○	○	○
48										

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COMBUSTION GAS TURBINE (API 616-5 th) DATASHEET U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ______ OF ______ BY ______

1	**ALARMS AND SHUTDOWNS** (5.4.4)							
2								
3	**DESCRIPTION**	APPLIES TO:		(5.4.4.8.5) FIRST OUT ANNUNCIATED POINT IN VENDOR FURNISHED CONTROL PANEL		SENSING DEVICES TO BE FURNISHED BY		INDICATING LIGHT ONLY
4		SS	SEP					
5		OR	PT	ALARM	SHUT-	VENDOR	OTHERS	
6		GG			DOWN			
7	RADIAL SHAFT VIBRATION	○	○	○	○	○	○	☐
8	AXIAL THRUST POSITION	○	○	○	○	○	○	☐
9	OVERSPEED	○	○	○	○	○	○	☐
10	CASING VIBRATION	○	○	○	○	○	○	☐
11	HIGH THRUST BEARING TEMPERATURE	○	○	○	○	○	○	☐
12	HIGH RADIAL BEARING TEMPERATURE	○	○	○	○	○	○	☐
13	LOW FUEL SUPPLY PRESSURE	○	○	○	○	○	○	☐
14	HIGH FUEL FILTER Δ P	○	○	○	○	○	○	☐
15	GAS TURBINE TEMPERATURE SPREAD HIGH	○	○	○	○	○	○	☐
16	EXHAUST OVER TEMPERATURE	○	○	○	○	○	○	☐
17	FAILURE OF OVER-TEMPERATURE SHUTDOWN DEVICE	○	○	○	○	○	○	☐
18	HIGH INLET AIR Δ P EACH FILTER	○	○	○	○	○	○	☐
19	COMBUSTOR FLAME-OUT	○	○	○	○	○	○	☐
20	CHIP DETECTOR, ANTI FRICTION BEARING	○	○	○	○	○	○	☐
21	FAILURE STARTING CLUTCH TO ENGAGE OR DISENGAGE	○	○	○	○	○	○	☐
22	LOW OIL PRESSURE	○	○	○	○	○	○	☐
23	HIGH LUBE OIL TEMPERATURE	○	○	○	○	○	○	☐
24	LOW LUBE OIL RESERVOIR LEVEL	○	○	○	○	○	○	☐
25	HIGH LUBE OIL RESERVOIR LEVEL	○	○	○	○	○	○	☐
26	HIGH OIL FILTER Δ P	○	○	○	○	○	○	☐
27	LUBE OIL SPARE PUMP OPERATING	○	○	○	○	○	○	☐
28	LOW CONTROL OIL PRESSURE	○	○	○	○	○	○	☐
29	LOW STARTING GAS PRESSURE	○	○	○	○	○	○	☐
30	ANTI-ICING SYSTEM - NOT OPERATING	○	○	○	○	○	○	☐
31	LOW D.C. VOLTAGE	○	○	○	○	○	○	☐
32	EMERGENCY D.C. PUMP OPERATING	○	○	○	○	○	○	☐
33	RESERVOIR HEATER "ON"	○	○	○	○	○	○	☐
34	IMPLOSION DOOR OPEN	○	○	○	○	○	○	☐
35	EXTERNAL PERMISSIVE START SIGNAL	○	○	○	○	○	○	☐
36	EXTERNAL SHUTDOWN SIGNAL	○	○	○	○	○	○	☐
37	LOSS OF AUXILIARY COOLING AIR	○	○	○	○	○	○	☐
38	LAMP TEST PUSH BUTTON	○	○	○	○	○	○	☐
39	ENCLOSURE HIGH TEMPERATURE	○	○	○	○	○	○	☐
40	CONTROL SIGNAL FAILURE	○	○	○	○	○	○	☐
41	CONTROL SYSTEM ACTUATOR FAILURE	○	○	○	○	○	○	☐
42	GOVERNOR FAILURE	○	○	○	○	○	○	☐
43	ENCLOSURE VENT FAN FAILURE	○	○	○	○	○	○	☐
44	SPARE ENCLOSURE VENT FAN OPERATING	○	○	○	○	○	○	☐
45	WOBBE METER	○	○	○	○	○	○	☐
46	GAS CHROMATOGRAPH	○	○	○	○	○	○	☐
47	EXHAUST GAS ANALYZER	○	○	○	○	○	○	☐
48	**NOTES:** (1) VENDOR TO ADVISE METHOD OF ANNUNCIATION		**GAUGE BOARD:**					
49	(2) VDU MAY USE MESSAGE INDICATOR		☐ LOCATION ______					

	JOB NO. ITEM NO.
COMBUSTION GAS TURBINE (API 616-5th) **DATASHEET** **U.S. CUSTOMARY UNITS**	REVISION DATE PAGE OF BY

ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER

STARTING AND HELPER DRIVERS (5.1.1)

○ STARTER ONLY ○ STARTER/HELPER (5.1.1.1)
TYPE (5.1.1.4) ○ MOTOR: ○ API 541 ○ API 546 ○ IEC 60034-1
○ GAS EXPANDER ○ IC ENGINE ○ HYDRAULIC
○ GAS TURBINE ○ STARTER IS CLUTCHED (5.1.1.7)
○ HELPER RATING (5.1.2.2) hp
☐ STARTER RATING (5.1.2.1) hp
○ SHAFT TURNING DEVICE REQ'D (5.1.3.1)

☐ MOTOR (STARTER ONLY):
TYPE RATING hp
MFR MODEL
○ REDUCED VOLTAGE STARTING (%) (5.1.1.5)

☐ MOTOR (STARTER / HELPER):
TYPE RATING
MFR MODEL
○ REDUCED VOLTAGE STARTING (%) (5.1.1.5)

☐ GAS EXPANDER
APPLICABLE SPEC. (5.1.1.6)
MFR MODEL
hp MAX. GAS FLOW lb/hr
TOTAL/START lb
○ GAS FOR EXPANSION TURBINE:

	MIN	MAX	NORMAL
INLET PRESSURE psia			
EXHAUST PRESS psia			
GAS TEMPERATURE, °F INLET			
GAS TEMPERATURE, °F EXHAUST			
MOLECULAR WEIGHT			

SPEED CONTROL ○ GOVERNOR ○ PRESSURE REGULATOR

DESIGN DETAILS:	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 psig
CASING MATERIAL
SEAL TYPE

☐ INTERNAL COMBUSTION ENGINE
TYPE ○ SPARK IGNITED ○ DIESEL
APPLICABLE SPECIFICATION (5.1.1.6)
MANUFACTURER MODEL
SPEED r/min POWER hp

☐ STEAM TURBINE (REFERENCE API DATASHEETS)
MFR MODEL
hp MAX. STEAM FLOW lb/hr
TOTAL FLOW / START lb

○ GEARS: SEE SEPARATE API 613 GEAR DATASHEETS (5.2.1.1)
○ DRIVEN EQUIPMENT, SEE SEPARATE API DATASHEETS
○ FIRE PROTECTION EQUIPMENT (5.7.3.1)
○ TYPE ○ WATER MIST ○ CO_2
○ TYPE OF SENSOR ○ NUMBER OF DETECTORS
○ ULTRA VIOLET NUMBER
○ INFRA RED NUMBER
○ HEAT RISE NUMBER
○ ADDITIONAL LEVELS OF DETECTION (5.7.3.3)

MOUNTING PLATES (5.3)

○ TYPE (5.3.1.1) ○ SOLEPLATE ○ BASEPLATE
☐ SHIM PACK THICKNESS in.

BASEPLATE (5.3.2)

○ EQUIPMENT MOUNTED ON BASEPLATE (5.3.2.1)
○ GAS TURBINE, COMPRESSOR SKID(S), ACCESSORY SKID
○ SOLEPLATES REQUIRED (5.3.3.1) ○ DRIP RIM REQUIRED
○ SUB-SOLEPLATES REQUIRED (5.3.3.1) ○ LEVELING PADS (5.3.2.3)
○ COLUMN MOUNTING (5.3.2.4) (3-POINT)

ENCLOSURES (5.7.5)

○ ENCLOSURE REQUIRED
○ MATERIAL
○ ACOUSTICAL
○ WEATHERPROOF
○ SAFETY
○ FIRE PROTECTION
○ ADDITIONAL VENTILATION DUCTING (5.7.5.6.3)

COUPLINGS AND GUARDS (5.2.2)

○ SEE ATTACHED API-671 COUPLING DATASHEETS
○ COUPLINGS PER ISO 10441 (5.2.2.4)
☐ MFR ☐ TYPE
☐ MODEL ☐ GUARD SUPPLIED BY
☐ MAXIMUM OUTSIDE DIAMETER in.
☐ HUB WEIGHT lb
☐ SPACER LENGTH in. ☐ SPACER WEIGHT lb
○ IDLING ADAPTER REQUIRED ○ SOLE PLATE REQUIRED
○ GUARD SUPPLIED BY
TYPE: ○ FULLY-ENCLOSED ○ SEMI-OPEN ○ OTHER
LUBRICATING REQUIREMENTS:
○ NON-LUBE ○ GREASE ○ CONTINUOUS OIL LUBE
QUANTITY PER HUB lb or gal/min

REMARKS:

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COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER

INLET CONDITIONS (5.6.1)	INLET SYSTEM (5.6.2)
INLET METEOROLOGICAL CONDITIONS (5.6.1.8):	○ ANTI-ICING (5.6.1.7) ○ GAS TURBINE AIR INLET SCREEN (5.6.1.14)
○ WIND SPEED (mph) & DIRECTION ______	○ SINGLE STAGE WITH PROVISION FOR FUTURE EXTRA
○ WIND SPEED (mph) & DIRECTION FOR CONTAMINANTS ______	STAGES (5.6.2.1.2): ○ YES ○ NO
○ DRY BULB TEMP (F): MIN ______ MAX ______	○ IMPLOSION DOOR (5.6.2.1.8)
○ BAROMETRIC PRESSURE (psia) ______	○ INLET SYST. SUPPORT STEEL REQ'D. (5.6.2.1.9) MIN. HEIGHT (ft) ______
○ RAINFALL (MAX . RATE) (in./hr) ______	○ SEISMIC ZONE ______
○ SNOWFALL (MAX. RATE) (in./hr) ______	○ SELF CLEANING (PULSE TYPE) (5.6.2.2)
○ RELATIVE HUMIDITY WITH VARIATIONS ______	○ RELATIVE HUMIDITY SENSOR (5.6.2.2.2)
○ FOG OR MIST CONDITIONS ______	○ HIGH VELOCITY INLET SYSTEM (5.6.2.3):
○ ICING CONDITIONS	○ HIGHER EFFICIENCY FILTERS (5.6.2.3.1)
CHEMICAL CONTAMINANTS IN THE AIR (5.6.1.9.1):	○ ADDITIONAL VANE SEPARATOR (5.6.2.3.2)
○ SODIUM (Na)	☐ FILTRATION EFFICIENCY ______
○ POTASSIUM (K)	☐ FILTER MFR. ______ MODEL ______
○ CALCIUM (Ca)	☐ MAINTENANCE INTERVAL ______ MONTHS
○ CHLORIDE (Cl)	☐ CLEANING FREQUENCY ______ DAYS
○ SULPHATE (SO_4)	☐ MANOMETER MFR ______ MODEL ______
○ NITRATE (NO_3)	RANGE ______ in. H_2O
○ TRACE METALS (V, Pb, Ni, Zn) ______	☐ SYSTEM SITE RATED PRESSURE DROP ______ in. H_2O
○ SULPHUR DIOXIDE (SO_2)	@ 110% RATED AIR FLOW AND CLEAN FILTERS
○ AMMONIA (NH_3)	@ 110% RATED AIR FLOW AND DIRTY FILTERS, ALARM @ in. H_2O
○ NITROUS OXIDES (NO_X)	☐ DUCTING GAUGE / MATERIAL ______ / ______
○ HYDROCARBONS (VOC)	☐ EXPANSION JOINT MFR ______ TYPE ______
○ HYDROGEN SULPHIDE (H2S)	**INLET SILENCERS** (5.6.2.5):
○ CHLORINE GAS (Cl_2)	○ ALTERNATE SILENCER PLATE MATERIAL (5.6.2.5.4) ______
○ HYDROCHLORIC ACID (HCL)	☐ SILENCER MFR ______ Δ P ______ in. H_2O
○ NEON (Ne)	☐ SILENCER MATERALS ______
○ OZONE (O_3)	**INLET COOLERS** (5.6.2.6):
○ HELIUM (He)	○ EVAPORATIVE TYPE (5.6.2.6.1.1)
○ METHANE (CH_4)	○ LIQUID-TO-AIR TYPE (5.6.2.6.2.1)
○ KRYPTON (Kr)	COOLANT-SIDE CONDITIONS (5.6.2.6.2.3):
○ HYDROGEN (H_2)	○ MAX. AVAILABLE FLOW (gal/min) ______
○ NITROUS OXIDE (N_2O)	○ MAX. TEMP (F) ______ MIN TEMP (F) ______
○ CARBON MONOXIDE (CO)	○ MAX. PRESS. (psia) ______ MIN. PRESS. (psia) ______
○ XENON (Xe)	○ COOLANT COMPOSITION OR ANALYSIS ______
○ NITROGEN DIOXIDE (NO_2)	☐ EXCHANGER MFR ______
PARTICULATE CONTAMINANTS IN AIR (5.6.1.9.2): (lb/SCFM)	☐ MODEL ______ Δ P ______ in. H_2O
○ SEA WATER ______	
○ COASTAL WATER ______	**REMARKS:** ______
○ ROADS WITH HEAVY TRAFFIC ______	
○ DRY LAKE BED ______	
○ NEARBY COOLING TOWER ______	
○ PERTROCHEMICAL INDUSTRY ______	
○ FOSSIL FIRED POWER PLANT ______	
○ GENERAL CHEMICAL INDUSTRY ______	
○ PAPER AND PULP INDUSTRY ______	
○ CEMENT PRODUCTION ______	
○ QUARRIES ______	
○ AGRICULTURAL ACTIVITIES ______	
○ PRODUCTION OF FERTILIZERS ______	
○ MINING AND METALLURGICAL ACTIVITIES	

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COMBUSTION GAS TURBINE (API 616-5 th) **DATASHEET** **U.S. CUSTOMARY UNITS**	JOB NO. ______ ITEM NO. ______ REVISION ______ DATE ______ PAGE ____ OF ____ BY ______

ACCESSORIES SUPPLIED BY GAS TURBINE MANUFACTURER

EXHAUST SYSTEM

○ EXHAUST HEAT RECOVERY SYSTEM (5.6.1.5) ______
○ RELIEF VALVE (5.6.1.6) ○ DIVERSION VALVE (5.6.1.6)
☐ ATMOSPHERIC RELIEF DEVICE
TYPE ______ MFR ______ LOCATION ______
☐ EXPANSION JOINT MFR ______ TYPE ______
☐ HEAT RECOVERY DEVICE TYPE ______
☐ MFR ______ Δ P ______ in. H_2O
☐ STEAM GEN: PRESS ______ psig TEMP ______ °F
RATE ______ lb/hr
○ EXHAUST SILENCER PLATE ELEMENT MATERIAL (5.6.3.1.3)
______
○ EXHAUST SILENCER EXIT STACK SUPPORT REQ'MTS (5.6.3.1.5)
______
☐ SILENCER ______ Δ P ______ in. H_2O
☐ DUCTING GAUGE / MATERIAL ______ / ______
○ EMISSIONS SAMPLING SYSTEM (5.6.3.2.4) ______
○ EMISSION CONTROL SYSTEM ______
○ EXTENT OF FURNISHED INSULATION (SEE SKETCH) (5.7.1.2)
○ EXHAUST STACK MTL. ______
☐ MANOMETER MFR ______
MODEL ______ RANGE ______ in. H_2O
☐ SYSTEM SITE RATED PRESS. DROP ______ in. H_2O

ATMOSPHERIC EMISSIONS

○ EMISSION SUPPRESSION SYSTEM REQUIRED (5.8.7.1)
○ NO_x REQUIREMENTS (5.8.7.2) ______
☐ NO_x EMITTED ______
EMISSIONS REDUCTION METHOD (IF REQUIRED)(5.8.7.2)
☐ WATER INJECTION (5.8.7.4) ☐ SCR
☐ STEAM (5.8.7.4) ○ DRY COMBUSTOR
○ OTHER ______
○ SO_x REQUIREMENTS ______
○ SULFUR CONTENT OF FUEL ______
SO_x EMITTED (BASED ON STATED SULFUR CONTENT)
______
○ CO REQUIREMENTS
☐ CO / CO_2 EMITTED ______
○ PARTICULATE REQUIREMENTS ______
☐ PARTICULATE EMITTED ______
○ UNBURNED HC REQUIREMENTS ______
☐ UNBURNED HC EMITTED ______
APPLICABLE EMISSION CODES OR REGULATIONS
○ EPA - TITLE 40 - CFR ○ OTHERS ______
EMISSION LEVEL (5.8.7.3)
○ INSTANTANEOUS (PPMV) ○ ANNUAL RATE (tons/yr)
○ PROVIDE EMISSIONS WITH & WITHOUT SUPPRESSION (5.8.7.4.1)

FIRE PROTECTION (5.7.3)

○ DESIGN STANDARDS (5.7.3.1):
○ NFPA ______ ○ ISO ______
FIRE EXTINGUISHING SYSTEM (5.7.3.1.1 & 5.7.3.1.2):
○ NFPA 2001 CLEAN AGENT
○ NFPA 750 WATER MIST
○ NFPA 12 CARBON DIOXIDE
○ ISO 14520 CLEAN AGENT
○ ISO 6183 CARBON DIOXIDE
FIRE DETECTION SYSTEM (5.7.3.3):
○ NFPA 72E
○ ISO 13387-7
GAS DETECTION SYSTEM (5.7.3.4)
○ NFPA 72E
○ IEC 61779-1

REMARKS: ______

ACOUSTICAL TREATMENT (5.7.4)

○ SPECIAL FAR FIELD RESTRICTIONS (5.7.4.2) ______
REMARKS: ______

ENCLOSURES (5.7.5)

○ ENCLOSURE REQUIRED, SPECIFY DETAILS (5.7.5.1):

REMARKS: ______

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	JOB NO. ______ ITEM NO. ______
COMBUSTION GAS TURBINE (API 616-5 th)	REVISION ______ DATE ______
DATASHEET	PAGE ______ OF ______ BY ______
U.S. CUSTOMARY UNITS	

INSPECTION AND TESTING; CONTROLS AND INSTRUMENTATION

SHOP INSPECTION AND TESTS: (6.1.1)	REQ	WIT	OBS
SHOP INSPECTION (6.1.2)	○		
CLEANLINESS (6.2.3.1)	○	○	
HYDROSTATIC (6.3.2)	○	○	○
PNEUMATIC (6.3.3)	○	○	○
MECHANICAL RUN (6.3.4)	○	○	○
AUXILIARY SYSTEMS (6.3.4.1.6) SPECIFY	○	○	○
CONTRACT CPLG IDLING ADAPTOR(S)			
VIB. PROBES CONTRACT SHOP			
VIBRATION PLOTS (6.3.4.3.4)	○		
TAPE RECORD VIB DATA (6.3.4.3.6)	○		
SPARE ROTOR (6.3.4.4.2)	○	○	○
PERFORMANCE TEST (6.3.5.1)	○	○	○
COMPLETE UNIT TEST (6.3.5.2)	○	○	○
PACKAGE TEST (6.3.5.2.1)	○	○	○
TORSIONAL VIBRATION (6.3.5.2.2)	○	○	○
LOAD GEAR TEST (6.3.5.3)	○	○	○
SOUND LEVEL TEST (6.3.5.4)	○	○	○
ROTOR OVERSPEED (6.3.5.5)	○	○	○
AUXILIARY EQUIPMENT (6.3.5.6)	○	○	○
VENTILATION SYSTEM VALIDATION (6.3.5.7)	○	○	○
ENCLOSURE LEAK TEST (6.3.5.8)	○	○	○
POST TEST INSPECTION (6.3.5.9)	○	○	○
HYDRAULIC COUPLING INSP (6.3.5.10)	○	○	○
GOVERNOR RESPONSE TEST (6.3.5.11)	○	○	○
SPARE PARTS (6.3.5.12)	○	○	○
FIRE PROTECTION (6.3.5.13)	○	○	○
UNIT CONTROL PANEL F.A.T.	○	○	○
OTHER (6.3.5.14)	○	○	○
GT FIELD PERFORMANCE TEST (6.3.6)	○	○	○
FIT UP & ASSEMBLY OF COMPONENTS (6.4.9)	○	○	○

CONTROL SYSTEMS

TYPE (5.4.1.8):
○ MECH ○ PNEU ○ HYDRAULIC ○ ELECTRIC ○ ELECTRONIC
○ MICROPROCESSOR BASED ○ COMBINED
○ MONITORS PER API 670: ○ 5.4.7.5 ○ 5.4.7.8.2 ○ 5.4.7.8.4
○ SIGNAL SOURCE ______
○ SENSITIVITY ______ ○ RANGE ______ TO ______
○ TIME OF AC OUTAGE PROTECTION (5.4.1.9) ______ MINUTES

CONTROL CONSOLES (5.4.5.1.1)
○ ON-SKID ○ OFF SKID LOCAL ○ OFF SKID REMOTE
WEATHER PROTECTION REQUIRED ○ YES ○ NO

HUMAN MACHINE INTERFACE KEYBOARD

STARTING SYSTEM (5.4.2.1)
○ MANUAL ○ SEMI AUTOMATIC ○ AUTOMATIC
PURGE (5.4.2.2) ______ MINUTES
○ SEPARATE SHUTDOWN VALVE TEST DURING OPERATION

MATERIALS INSPECTION REQUIREMENTS (6.2.1.3)
○ ALTERNATE INSPECTION PROCEDURES (6.2.2.1.1) SPECIFY
○ SPECIAL CHARPY TESTING (4.10.5.3) ______
○ RADIOGRAPHY REQUIRED FOR ______
○ MAGNETIC PARTICLE REQUIRED FOR ______
○ LIQUID PENETRANT REQUIRED FOR ______
○ ULTRASONIC REQUIRED FOR ______
○ QUALITY CONTROL OF INACCESSIBLE WELDS (4.10.4.6.2)
○ 100% INSPECTION OF WELDS (4.10.4.7.1)
○ INSPECTION PRIOR TO CLOSING OPENINGS (6.2.3.3)
○ WELDING HARDNESS TESTING (6.2.3.4)
○ POSITIVE MATERIAL IDENTIFICATION (4.10.1.14.1) ATTACH LIST
○ ADDITIONAL COMPONENTS FOR PMI (4.10.1.14.2) ATTACH LIST

MISCELLANEOUS INSPECTION AND TESTING:
○ SITE TEST OF GT AND DRIVEN EQUIPMENT (4.1.17)
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION [4.1.18 a)]
○ OBSERVE PARTING OF FLANGES [4.1.18 b)]
○ CHECK ALIGNMENT AT OPERATING TEMPERATURE [4.1.18 c)]
WITNESS INITIAL ALIGNMENT CHECK [4.1.18 d)]
○ FINAL ASSEMBLY CLEARANCES [6.2.1.1 d)] AT GT VENDOR SHOP

SPECIALIZED INSTRUMENTS AND CONTROLS

TACHOMETERS: (5.4.7.2.2)
TYPE ○ ELECTRICAL ○ ELECTRONIC
○ ANALOG ○ DIGITAL
○ MANUFACTURER ______
○ GLYCERIN-FILLED PRESSURE GAUGES (5.4.7.6)
CONTROL WIRING (5.4.5.3.2): ○ ARMORED ○ METAL CONDUIT
SWITCHES: (5.4.4.8.2) CIRCUIT SHALL:
○ ENERGIZE ○ DEENERGIZE TO ALARM
○ ENERGIZE ○ DEENERGIZE TO SHUTDOWN
INSTRUMENT / ELECTRICAL ENCLOSURES
○ EXPLOSION PROOF ○ WEATHER PROOF
CONTROL / INSTRUMENT WIRING (5.4.5.3.2) ○ ARM. CABLE ○ CONDUIT
CONTROL SYSTEM DETAILS:
○ ALARM & SHUTDOWN ARRANGEMENTS (5.4.4.8)
○ ALARM & SHUTDOWN SWITCHES (5.4.4.8.1)
○ FIRST-OUT ANNUNCIATOR REQ'D (5.4.4.8.5)
○ PURGE FIRST-OUT ANNUNCIATOR REQ'D [5.4.4.8.5 b)]
○ SHUT OFF VALVES FOR SHUT DOWN SENSORS (5.4.4.9)
○ SHUTDOWN DEVICE ISOLATION LOCKOUT (5.4.4.10)

LOAD CONTROL - GOVERNOR (5.4.3)

○ MFR'S STD. ○ OTHER ○ MAKE ______ ○ MODEL ______
○ CONSTANT SPEED ○ VARIABLE SPEED
○ ISOCHRONOUS ○ DROOP
REMOTE SHUTDOWN SIGNAL, SPECIFY TYPE: ______
○ CONTROL SIGNAL RANGE (5.4.3.3) ______
MANUAL SPEED CHANGER, r/min ______ MAX. ______ MIN.
○ MAINTAIN TURBINE SPEED UPON FAILURE OF CONTROL SIGNAL OR ACTUATOR

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JOB NO. ______ ITEM NO. ______

REVISION ______ DATE ______

PAGE ______ OF ______ BY ______

COMBUSTION GAS TURBINE (API 616-5 th)
DATASHEET
U.S. CUSTOMARY UNITS

LUBRICATION, WEIGHTS & VENDOR DATA

☐ **WEIGHTS**	DRY INSTALLED (lb)	SHIPPING (lb)	DIMENSIONS LxWxH (ft)
GAS GENERATOR			
POWER TURBINE			
GT ENCLOSURE			
INLET FILTER HOUSE			
INLET AIR DUCTING			
VENT DUCTING			
EXHAUST DUCTING			
EXHAUST STACK			
MIN OIL CONSOLE			
SYN OIL CONSOLE			
MIN OIL SEPARATOR			
SYN OIL SEPARATOR			
MIN OIL AIR COOLER			
SYN OIL AIR COOLER			
HYD START SKID			
CO_2 CYLINDER SKID			
WATER WASH SKID			
TOTAL PACKAGE WT			
MAX ERECTION WT		ITEM	
MAX MAINT WT		ITEM	

VENDOR'S DATA:

- ○ COORDINATION MEETING SITE (7.1.3) ______
- ○ SPARE PARTS OPTIMIZATION ANALYSIS [(7.2.3 v)]
- ○ FAILURE MODES AND EFFECTS ANALYSIS [7.2.3 w)]
- ○ LIFE CYCLE COST ANALYSIS [7.2.3 x)]

PERFORMANCE CURVES (7.2.4)

- ○ SPEED-TORQUE CURVE OF OUTPUT SHAFT [7.2.4 a]
- ○ INCREMENTAL POWER FOR STEAM/WATER [7.2.4 b)]
- ○ EFFECTS OF AMB. COND. ON EXHAUST FLOW [7.2.4 c)]
- ○ RUN DOWN CURVES [7.2.4 d)]
- ○ NO_X AND CO_2 EMISSIONS [7.2.4 e)]
- ○ IMPACT OF ANTI-ICING SYSTEM [7.2.4 f)]

- ○ PROGRESS REPORTS (7.3.4)
- ○ TECHNICAL DATA MANUAL (7.3.6.4)

REMARKS:

LUBRICATION SYSTEMS (4.9)

○ API 614 DATASHEETS ______

☐ **MINERAL** LUBE SYSTEM (4.9.5) ○ OIL VISCOSITY ______

COMMON TO: ▢ GAS GENERATOR or SINGLE SHAFT GT; ▢ FREE POWER TURBINE; ▢ LOAD GEAR; ▢ DRIVEN EQUIPMENT; ▢ AUXILIARIES

○ **SYNTHETIC** LUBE OIL SYSTEM (4.9.2) ☐

☐ LUBE SPECIFICATION ______

COMMON TO: ▢ GAS GENERATOR; ▢ POWER TURBINE; ▢ LOAD GEAR; ▢ DRIVEN EQUIPMENT; ▢ AUXILIARIES; ▢ ______

○ OIL DEBRIS MONITORING ______

☐ **OIL REQUIREMENTS**	FLOW (gal/min)	PRESSURE (psig)	HEAT LOAD (hp)
GAS GENERATOR			
POWER TURBINE			
HYD START SYSTEM			

MINERAL OIL RESERVOIR CAPACITY ______ gallons

SYNTHETIC OIL RESERVOIR CAPACITY ______ gallons

HYDRAULIC OIL RESERVOIR CAPACITY ______ gallons

HYDRAULIC OIL SPECIFICATION

MOUNTING ARRANGEMENT: ○ CONSOLE ○ COLUMN ○ BASEPLATE

REMARKS:

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Annex B
(normative)

Gas Turbine Vendor Drawing and Data Requirements (VDDR)

GAS TURBINE
VENDOR DRAWING AND
DATA REQUIREMENTS

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

FOR ______________
SITE ______________
SERVICE ______________

REVISION ______________
UNIT ______________
NO. REQUIRED ______________

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

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

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

DISTRIBUTION RECORD

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

Proposal	Review	Final	DESCRIPTION	Review—Due from Vendor	Review—Received from Vendor	Review—Returned to Vendor	Final—Due from Vendor	Final—Received from Vendor
			1. Certified dimensional outline drawing and list of connections					
			2. Cross-sectional drawing and bill of materials					
			3. Rotor assembly drawings and bills of materials					
			4. Thrust-bearing assembly drawing and bill of materials					
			5. Journal-bearing assembly drawings and bills of materials					
			6. Shaft-coupling assembly drawings and bills of materials					
			7. Bleed-air/cooling-air sealing and leak-off schematics and bills of materials					
			8. Fuel-system schematics and bills of materials					
			9. Fuel-system component assembly drawings and lists of connections					
			10. Lube-oil/control-oil schematics and bills of materials					
			11. Lube oil, control oil and water washing arrangement drawings and list of connections					
			12. Electrical and instrumentation schematics and bills of materials					
			13. Electrical and instrumentation arrangement drawings and lists of connections					
			14. Governor, control, and trip system data					
			15. Injection-system schematic and bill of materials (optional)					
			16. Injection-system arrangement drawings (optional)					
			17. Tabulation of utility requirements					
			18. Curves showing certified shaft speed vs power at site rated conditions (see Figure 14, Figure 15, or Figure 16)					
			19. Curve showing ambient temperature vs rated power curve including heat rate and speed					
			20. Curve showing output-power shaft speed vs torque					
			21. Curves showing incremental power output vs water- or steam-system injection rate					
			22. Heat-rate correction factors					
			23. Thrust-bearing performance data					
			24. Blade vibration analysis data. For new or prototype equipment, blade data shall be reviewed at the vendor's facility.					
			25. Lateral critical analysis report					
			26. Torsional critical analysis report					
			27. Transient torsional analysis report					
			28. Allowable flange loadings					
			29. Coupling alignment diagram					
			30. Welding procedures					

[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 desired time frame for submission of materials using the nomenclature given at the end of this form.
[c] Bidder shall complete these two columns to reflect his/her actual distribution schedule and shall include this form with his/her proposal.

GAS TURBINE VENDOR DRAWING AND DATA REQUIREMENTS

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

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

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

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

DISTRIBUTION RECORD

Proposal	Review	Final	DESCRIPTION	Review—Due from Vendor [c]	Review—Received from Vendor	Review—Returned to Vendor	Final—Due from Vendor [c]	Final—Received from Vendor
			31. Certified hydrostatic test logs					
			32. Mechanical running test logs					
			33. Performance test logs					
			34. Nondestructive test procedures					
			35. Inspection and test plans and test procedures					
			36. Certified mill test reports					
			37. Rotor balancing logs					
			38. Rotor combined mechanical and electrical runout					
			39. As-built datasheets					
			40. As-built dimensions and data					
			41. Installation manual					
			42. Operating and maintenance manuals					
			43. Spare-parts recommendations including commissioning, start-up, two-years operating and insurance capital spares					
			44. Engineering, fabrication, and delivery schedule (progress reports)					
			45. List of drawings					
			46. Shipping lists					
			47. List of special tools furnished for maintenance					
			48. Technical data manual					
			49. Material Safety Datasheets					
			50. Preservation, packaging, shipping and commissioning procedures					
			51. Bearing babbitt strength vs temperature curves					
			52. Noise data					
			53. Pre-commissioning meeting agenda and documentation					

[a] Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.

Notes:

1. The vendor shall 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.

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

Vendor ____
Date ______________________ Vendor Reference ______________________
Signature ____

(Signature acknowledges receipt of all instructions)

Descriptions

1) Certified dimensional outline drawings and list of connections, including the following:

   a) size, rating and location of all customer connections;

   b) approximate overall handling weights;

   c) certified maximum single-lift weight;

   d) overall dimensions, maintenance clearances and dismantling clearances;

   e) shaft centerline height;

   f) enclosure drawings and details;

   g) air inlet system, including inlet silencer, inlet air humidification system (if provided) and inlet air chilling coil (if provided);

   h) exhaust system, including exhaust silencer, waste heat recovery unit (if provided) and bypass stack (if provided);

   i) “ship loose” auxiliary system skids, i.e. water wash system, hydraulic starter system, liquid fuel pump system, gas filter(s) (if provided);

   j) dimensions of baseplates (if furnished) complete with diameter, number and locations of bolt holes and thickness of the metal through which the bolts must pass and recommended clearance; centers of gravity; and details for foundation design;

   k) baseplate finite element analysis or structural analysis for all new baseplate designs and all 3-point mount baseplates;

   l) baseplate lifting lug and lifting beam structural analysis and drawings;

   m) direction of rotation;

2) Cross-sectional drawing and bill of materials, including the following:

   a) journal bearing clearances and tolerances;

   b) axial rotor float for all rotors (compressor, gas generator, power turbine);

   c) shaft end and internal labyrinth seal clearances and tolerances;

   d) axial position or rotor disks, blades relative to inlet nozzles or vanes and tolerances allowed;

   e) outside diameter of all disks at the blade tip.

3) Rotor assembly drawings and bills of materials, including the following.

   a) Axial position from the active thrust collar face to:

1) each impeller or rotating disk, inlet side;

2) each radial probe;

3) each journal bearing centerline;

4) phase angle notch;

5) coupling face or end of shaft.

b) Thrust collar assembly details, including:

1) collar shaft with tolerance,

2) concentricity (or axial runout) tolerance,

3) required torque for locknut,

4) surface finish requirements for collar faces,

5) preheat method and temperature requirements for shrunk-on collar installation.

c) Dimensional shaft ends for collar faces.

4) Thrust bearing assembly and bill of materials.

5) Journal bearing assembly drawings and bills of materials for all field-maintainable rotors.

6) Shaft coupling assembly drawings and bills of materials, including the following:

a) hydraulic mounting procedure,

b) shaft end gap and tolerance,

c) coupling guards,

d) thermal growth from a baseline of 60 °F (15 °C),

e) manufacturer, size and serial number,

f) axial natural frequency over allowable spacer stretch (disc-type coupling),

g) balance tolerance,

h) coupling “pull-up” mounting dimensions.

7) Bleed-air/cooling-air sealing and leak-off schematics and bills of materials, including the following:

a) steady state and transient air and gas flows and pressures;

b) relief and control valve settings;

c) utility requirements, including electricity, water steam and air;

d) pipe and valve sizes;

e) instrumentation, safety devices and control schemes;

f) list of purchaser connections (if any).

8) Fuel system schematics, bills of materials and data, including the following:

a) fuel compressor/pump performance curves;

b) control valves, relief valves and instrumentation schematics;

c) vacuum pump schematic, performance curves, cross-section, outline drawing and utility requirements (if pump is furnished).

9) Fuel system component assembly drawings and lists of connections, including the following:

a) fuel compressors or pumps,

b) control and relief valves and instruments,

c) steam/water injection (if used).

10) Lube oil/control oil schematics and bills of materials, including the following:

a) steady state and transient oil flows and pressures at each use point;

b) control, alarm and trip settings (pressures and recommended temperatures);

c) supply temperature and heat loads at each use point at maximum load;

d) utility requirements, including electricity, water and air;

e) pipe and valve sizes;

f) instrumentation, safety devices and control schemes.

11) Lube oil, control oil, online water washing and offline water washing system and arrangement drawings, including size, rating and location of all customer connections.

12) Electrical and instrumentation schematics and bills of materials for all systems, including the following:

a) starting (direct drive motor or hydraulic) system schematic and bill of materials,

b) anti-icing system schematic and bill of materials,

c) gas detection/fire protection schematic and bills of materials,

d) control system logic diagram,

e) all schematics shall show all alarm and shutdown limits (set points).

13) Electrical and instrumentation arrangement drawings and lists of connections, including the following:

a) control panel elevation drawings,

b) junction boxes for customer interface points.

14) Governor, control and trip system data, including the following:

a) firing sequence and final settings,

b) control and trip settings,

c) control setting instructions,

d) governor cross-section and setting instructions.

15) Injection system schematic and bill of materials, including steady-state and transient flows and pressures at each use point.

16) Injection system arrangement, including the size, rating, and location of all customer connections.

17) Tabulation of utility requirements, including the following:

a) lube oil quantity and quality specification,

b) instrument air,

c) nitrogen requirements,

d) water for online and offline washing.

18) Curves showing certified shaft speed vs power at site rated conditions with normal fuel (see Figure 14, Figure 15, or Figure 16). After the order, these curves shall also show any limit on the driven load (such as compressor surge and generator output).

19) Curve showing ambient temperature vs rated power output at rated speed with normal fuel over the ambient range specified.

20) Curve showing output power shaft speed vs torque [include starter if applicable; see 7.2.4 a)].

21) Curves showing incremental power output vs water or steam system injection rate (required only if injection is supplied).

22) Heat rate correction factors for the curves listed in Items 18 through 20 and 22 at conditions other than site-rated as follows:

a) ambient pressure to maximum and minimum values listed on the datasheets in increments agreed upon at the time of the order (usually no significant change),

b) ambient temperature to maximum and minimum values listed on the datasheets in increments agreed upon at the time of the order,

c) output-power shaft speed from 80 % to 105 % in 5 % increments (two-shaft machines only),

d) exhaust pressure to maximum and minimum values listed on the datasheets in increments agreed upon at the time of the order,

e) injection system rate changes (fuel only treat injection liquid as compressed air).

23) Curves showing performance of thrust bearing embedded temperature elements as a function of load, shaft speeds and operating oil supply temperature.

24) Blade vibration analysis data, including the following:

a) tabulation of all potential excitation sources such as vanes, blades, nozzles and critical speeds;

b) Campbell diagram for each stage;

c) Goodman diagram for each stage.

25) Lateral critical speed analysis report, including but not limited to the following.

a) Complete description of the method used.

b) Graphic display of critical speeds vs operating speeds.

c) Graphic display of bearing and support stiffness and its effect on critical speeds.

d) Graphic display or rotor response to unbalance (including damping).

e) Journal static loads.

f) Stiffness and damping coefficients.

g) Tilting-pad bearing geometry and configuration, including:

1) pad angle (arc) and number of pads;

2) pivot offset;

3) pad clearance (with journal radius, pad bore radius and bearing-set bore radius);

4) preload.

26) Torsional critical analysis report, including but not limited to the following:

a) complete description of the method used,

b) graphic display of the mass-elastic solution,

c) tabulation identifying the mass moment and torsional stiffness of each component identified in the mass-elastic system,

d) graphic display of exciting forces vs speed and frequency,

e) graphic display of torsional critical speeds and deflections (mode-shape diagram),

f) effects of alternate coupling on the analysis.

27) Transient torsional analysis for all units using synchronous starter/helper motors (mandatory) or driving synchronous generators (optional).

28) Allowable flange loadings for all customer connections, including anticipated thermal movements referenced to a defined points.

29) Coupling alignment diagram, including recommended limits during operation. Note all shaft-end position changes and support growth from a reference point temperature of 59 °F (15 °C) or another temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.

30) Welding procedures for fabrication and repair (see 4.10.1.11, 4.10.4, and 6.2.2.1).

31) Certified hydrostatic test logs.

32) Mechanical running test logs, including but not limited to the following:

  a) oil flows, pressures and temperatures;

  b) vibration, including an x-y plot of amplitude and phase angle vs revolutions per minute during start-up and coast down;

  c) bearing metal temperatures;

  d) observed critical speeds (for flexible rotors);

  e) exhaust gas temperature;

  f) if specified, tape recordings of real-time vibration data (see 6.3.4.3.6).

33) Performance test logs and report in accordance with ASME PTC 22, Section 6, as supplemented by ASME PTC 1, Section3-11 Test Report, Paragraphs 3-11.1 and 3-11.2.

34) Nondestructive test procedures and acceptance criteria as itemized on the purchase order datasheets on the VDDR form.

35) Manufacturing inspection and testing plans and procedures, including the following:

  a) inspection plans;

  b) test plans;

  c) test procedures for standard, special or optional tests (see 6.3.5).

36) Certified mill test reports of items as agreed upon in the precommitment or inspection meetings.

37) Rotor balancing logs, including a residual unbalance report in accordance with Annex C.

38) Rotor combined mechanical and electrical runout in accordance with 4.7.5.2.3.

39) As-built datasheets, including the following:

  a) API 616 datasheets,

  b) API 614 datasheets,

c) API 613 datasheets (if load gear is provided),

d) ISA instrument datasheets.

40) As-built dimensions (including nominal dimensions with design tolerances) and data for the following listed parts.

a) Shaft or sleeve diameters at:

1) thrust collar (for separate collars),

2) each seal component,

3) each wheel (for stacked rotors) or bladed disk,

4) each interstage labyrinth,

5) each journal bearing,

b) Each wheel or disk bore (for stacked rotors) and outside diameter.

c) Each labyrinth or seal-ring bore.

d) Thrust collar bore (for separate collars).

e) Each journal bearing inside diameter.

f) Thrust bearing concentricity (axial runout).

g) Metallurgy and heat treatment for:

1) shaft;

2) impellers or bladed disks;

3) thrust collar;

4) blades, vanes and nozzles;

41) Installation manual describing the following (see 7.3.6.2):

a) storage procedures;

b) foundation plan;

c) grouting details;

d) setting equipment, rigging procedures, component weights and lifting diagrams;

e) coupling alignment diagram [per Item 29) above];

f) piping recommendations, including allowable flange loads;

g) composite outline drawings for the driver/driven equipment train, including anchor bolt locations;

h) dismantling clearances;

42) Operating and maintenance manuals describing the following (see 7.3.6.3).

a) Start-up.

b) Normal shutdown.

c) Emergency shutdown.

d) Operating limits (see 4.7.1.4), other operating restrictions and list of undesirable speeds (see 4.7.1.4).

e) Lube oil recommendations and specifications.

f) Routine operational procedures, including recommended inspection schedules and procedures.

g) Instruction for:

1) disassembly and reassembly or rotor in casing,

2) rotor unstacking and restacking procedures,

3) disassembly and reassembly of journal bearings (for tilting-pad bearings, the instructions shall include “go/no-go” dimensions with tolerances for three-step plug gauges),

4) disassembly and reassembly of thrust bearings,

5) disassembly and reassembly of seals (including maximum and minimum clearances),

6) disassembly and reassembly of thrust collar,

7) wheel reblading procedures,

8) Boring procedures and torque values.

h) Performance data, including:

1) curve showing certified shaft speed vs site rated power,

2) curve showing ambient temperature vs site rated power,

3) curve showing output-power shaft speed vs torque,

4) curve showing incremental power output vs water or steam injection rate (optional),

5) heat rate correction factors (optional),

6) thrust bearing performance data.

i) Vibration data, per Item 24 through Item 27 above.

j) As-built data, including:

1) as-built datasheets;
2) as-built dimensions or data, including assembly clearances;
3) hydrostatic test logs, per Item 31 above;
4) mechanical running test logs, per Item 32 above;
5) rotor balancing logs, per Item 37 above;
6) rotor mechanical and electrical runout at each journal, per Item 38 above;
7) physical and chemical mill certificates for critical components;
8) test logs of all specified optional tests.

k) Drawings and data, including:

1) certified dimensional outline drawing and list of connections;
2) cross-sectional drawing and bill of materials;
3) rotor assembly drawings and bills of materials;
4) thrust bearing assembly drawing and bill of materials;
5) journal bearing assembly drawings and bills of materials;
6) seal component drawing and bill of material;
7) lube oil schematics and bills of materials;
8) lube oil arrangement drawing and list of corrections;
9) lube oil component drawings and data;
10) electrical and instrumentation schematics and bills of materials;
11) electrical and instrumentation arrangement drawings and list of connections;
12) governor, control and trip system drawings and data;
13) trip and throttle valve construction drawings.

43) Spare parts list with stocking level recommendations, in accordance with 7.3.5, including the following:

a) commissioning spares,
b) startup spares,
c) two-year's operating spares,
d) insurance capital spares.

44) Progress reports and delivery schedule, including vendor buyouts and milestones. The reports shall include engineering, purchasing, manufacturing and testing schedules for all major components. Planned and actual dates and the percentage completes shall be indicated for each milestone in the schedule.

45) List of drawings, including latest revision numbers and dates.

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

47) List of special tools furnished for maintenance (see 5.9).

48) Technical data manual, including the following:

a) as-built purchaser datasheets, per Item 39 above;

b) certified performance curves, per Item 18 through Item 22 above;

c) drawings, in accordance with 7.3.2;

d) as-built assembly clearances;

e) spare parts list, in accordance with 7.3.5;

f) utility data, per Item 17 above;

g) blade vibration data, per Item 24 above;

h) reports, per Items 25, 26, 27, 29, 31, 32, 33, 37, and 38 above.

49) Material safety datasheets (OSHA Form 20).

50) Preservation, packaging, shipping and commissioning procedures, including the following:

a) painting specification;

b) preservation specification;

c) export boxing details along with proper lifting procedures;

d) commissioning procedures for cleaning and flushing of lube oil, hydraulic oil and fuel systems.

51) Bearing babbitt strength vs temperature curves.

52) Noise information, including the following:

a) inlet system noise spectrum,

b) gas turbine enclosure noise spectrum,

c) exhaust system noise spectrum.

53) Precommissioning meeting agenda and documentation.

Annex C
(normative)

Procedure for Determination of Residual Unbalance

Equipment (Rotor) No.:	__________	
Purchase Order No.:	__________	
Correction Plane (inlet, drive-end, etc.—use sketch):	__________	
Balancing Speed:	__________	rpm
N—Maximum Allowable Rotor Speed:	__________	rpm
W—Weight of Journal (closest to this correction plane):	__________	kg (lb)
U_{max}—Maximum Allowable Residual Unbalance = 6350 W/N (4 W/N) 6350 × ______ kg/______ rpm; 4 × ______lb/______rpm	__________	gm-mm (oz-in.)
Trial Unbalance (2 × U_{max}):	__________	gm-mm (oz-in.)
R—Radius (at which weight will be placed):	__________	mm (in.)
Trial Unbalance Weight = Trial Unbalance/R _____gm-mm/_____mm/______oz-in./______in.	__________	g (oz)

Conversion Information: 1 oz = 28.350 g

Test Data

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1		
2		
3		
4		
5		
6		
7		

Rotor Sketch

Test Data—Graphic Analysis

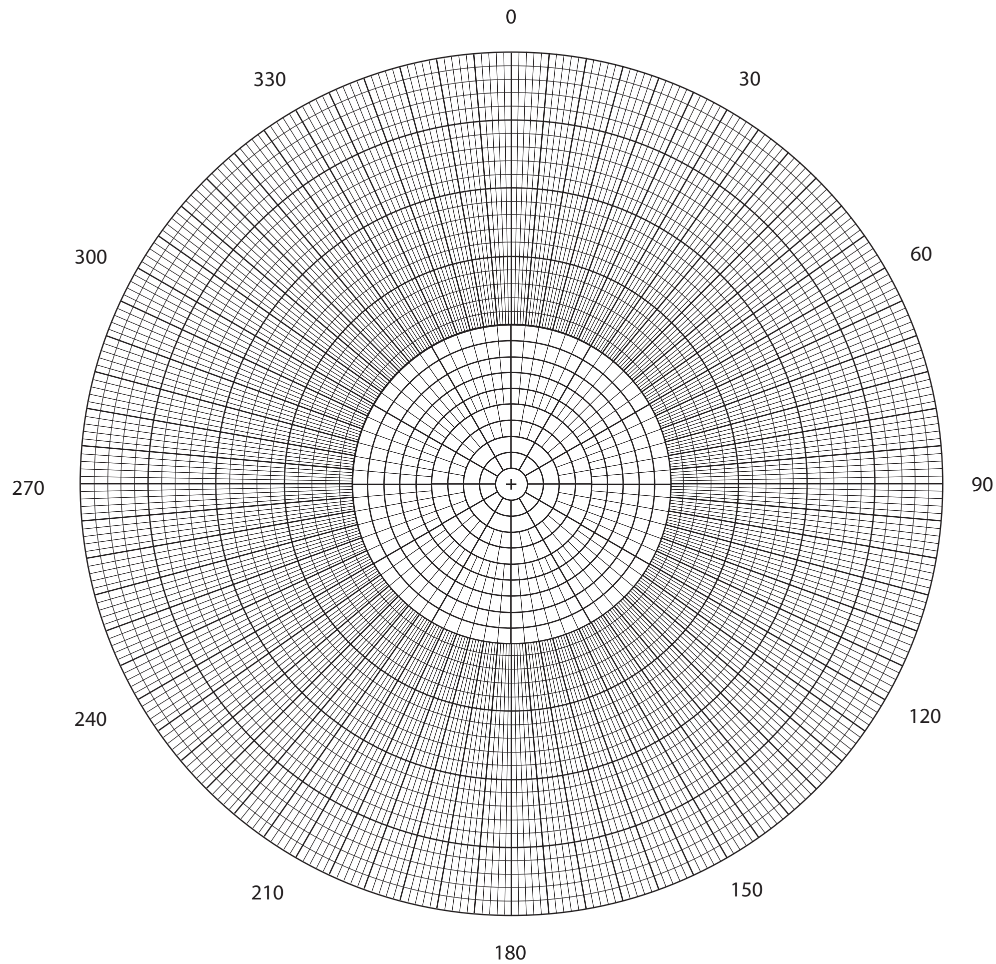
Step 1:	Plot data on the polar chart (Figure C.2). Scale the chart so the largest and smallest amplitude will fit conveniently.	
Step 2:	With a compass, draw the best fit circle through the six points and mark the center of this circle.	
Step 3:	Measure the diameter of the circle in the units of scale chosen in Step 1 and record.	units
Step 4:	Record the trial unbalance from above.	gm-mm (oz-in.)
Step 5:	Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).	gm-mm (oz-in.)
Step 6:	Divide the answer in Step 5 by the answer in Step 3.	Scale Factor

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

NOTE 1 The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.

NOTE 2 The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure C.1—Residual Unbalance Worksheet



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

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

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

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

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

Correction plane ____________________ for rotor no. ____________________ (has/has not) passed.

By ____________________ Date ____________________

Figure C.2—Residual Unbalance Worksheet

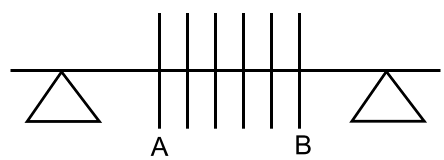
Equipment (Rotor) No.:	*C–101*	
Purchase Order No.:		
Correction Plane (inlet, drive-end, etc.—use sketch):	*A*	
Balancing Speed:	*800*	rpm
N—Maximum Allowable Rotor Speed:	*10,000*	rpm
W—Weight of Journal (closet to this correction plane):	*908*	~~kg~~ (lb)
U_{max}—Maximum Allowable Residual Unbalance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

Conversion Information: 1 oz = 28.350 g

Test Data

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1	*0*	*14.0*
2	*60*	*12.0*
3	*120*	*14.0*
4	*180*	*23.5*
5	*240*	*23.0*
6	*300*	*15.5*
7	*0*	*14.0*

Rotor Sketch



C-101

Test Data—Graphic Analysis

Step 1:	Plot data on the polar chart (Figure C.4). Scale the chart so the largest and smallest amplitude will fit conveniently.		
Step 2:	With a compass, draw the best fit circle through the six points and mark the center of this circle.		
Step 3:	Measure the diameter of the circle in the units of scale chosen in Step 1 and record.	*35*	units
Step 4:	Record the trial unbalance from above.	*0.72*	~~gm-mm~~ (oz-in.)
Step 5:	Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).	*1.44*	~~gm-mm~~ (oz-in.)
Step 6:	Divide the answer in Step 5 by the answer in Step 3.	*0.041*	Scale Factor

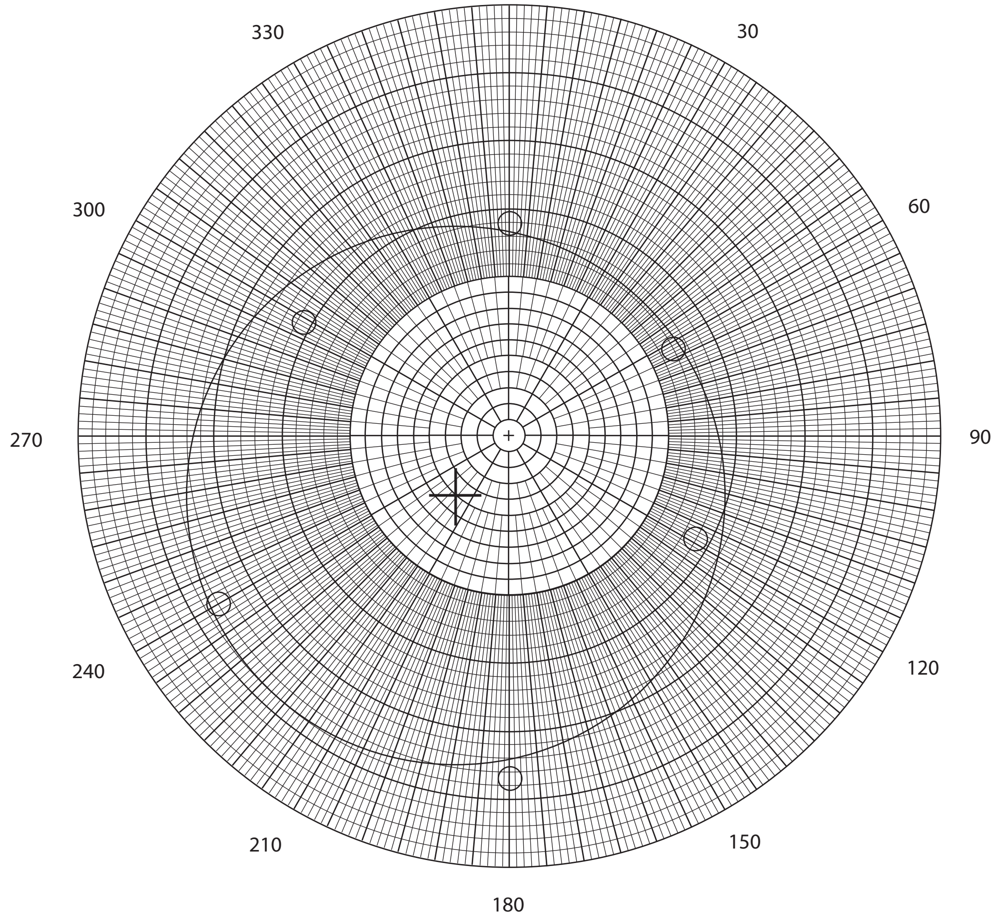
You now have a correlation between the units on the polar chart and the gm-in. of actual balance.

NOTE 1 The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.

NOTE 2 The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure C.3—Sample Calculations for Residual Unbalance [1]

1. This Example is merely an example for illustration purposes only. Each company should develop its own approach. It is not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.



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

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

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

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

Record allowable residual unbalance (from Figure C.3) *0.36* (~~gm-mm~~)(oz-in.)

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

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

Figure C.4—Sample Calculations for Residual Unbalance [1]

[1] This Example is merely an example for illustration purposes only. Each company should develop its own approach. It is not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

Annex D
(normative)

Torsional and Lateral Flowcharts

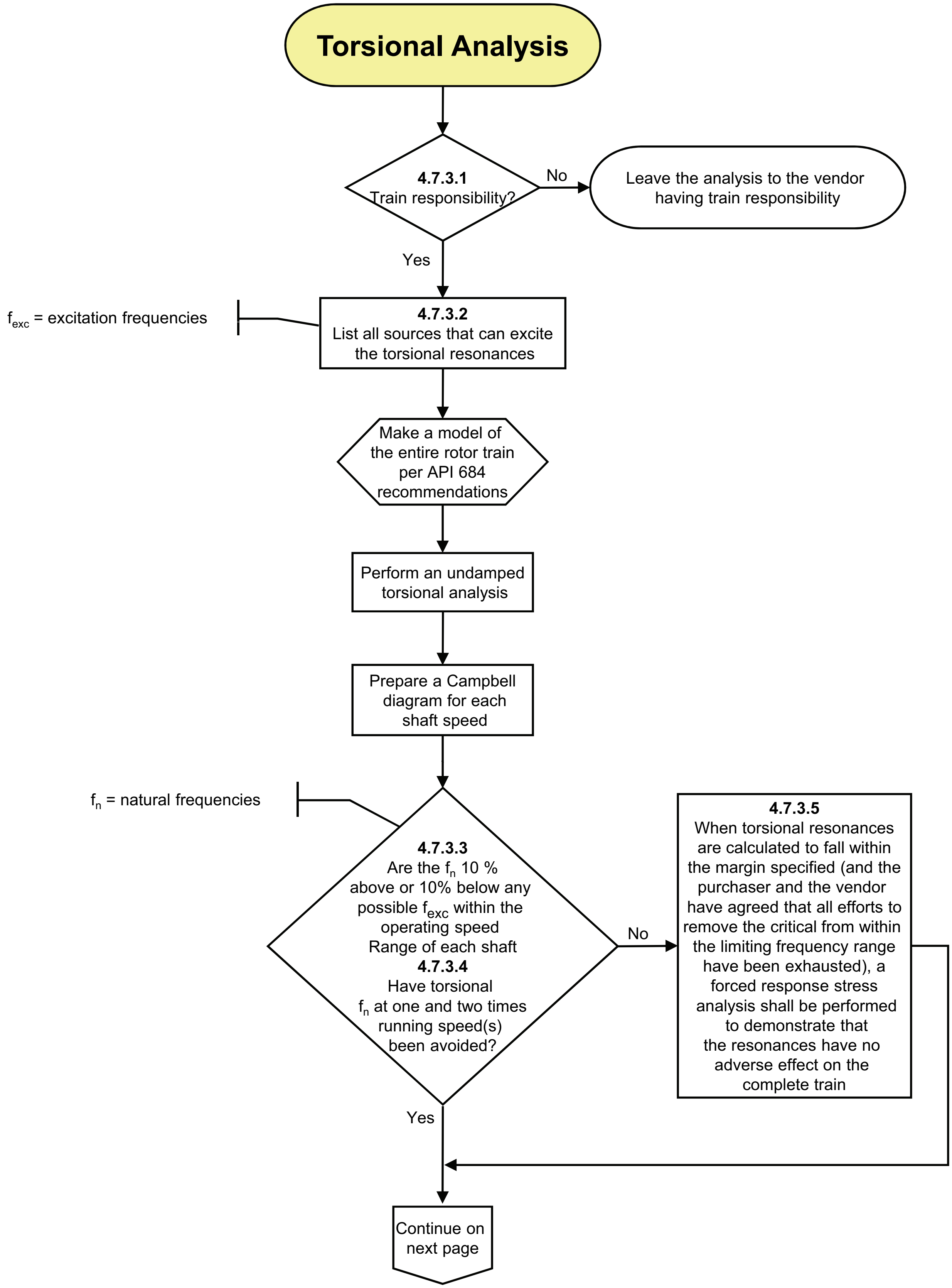


Figure D.1—Torsional Analysis Flowchart

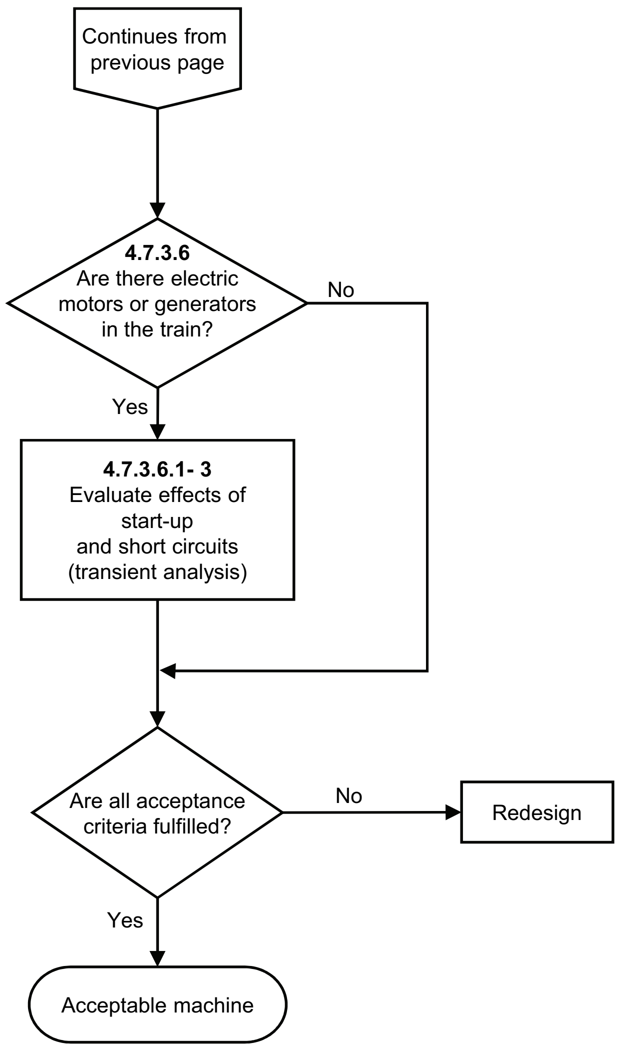


Figure D.1—Torsional Analysis Flowchart (continued)

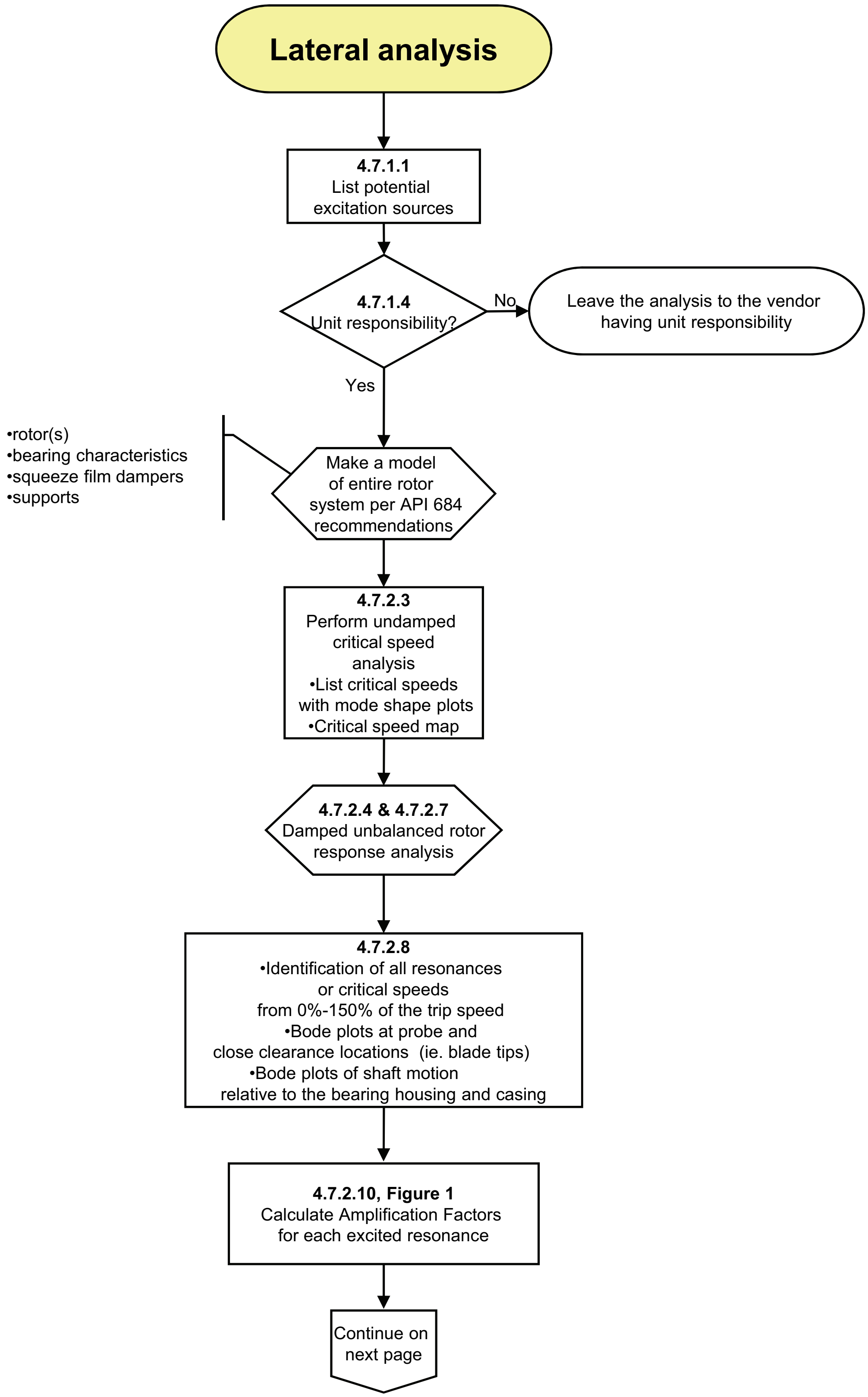


Figure D.2—Lateral Analysis Flowchart

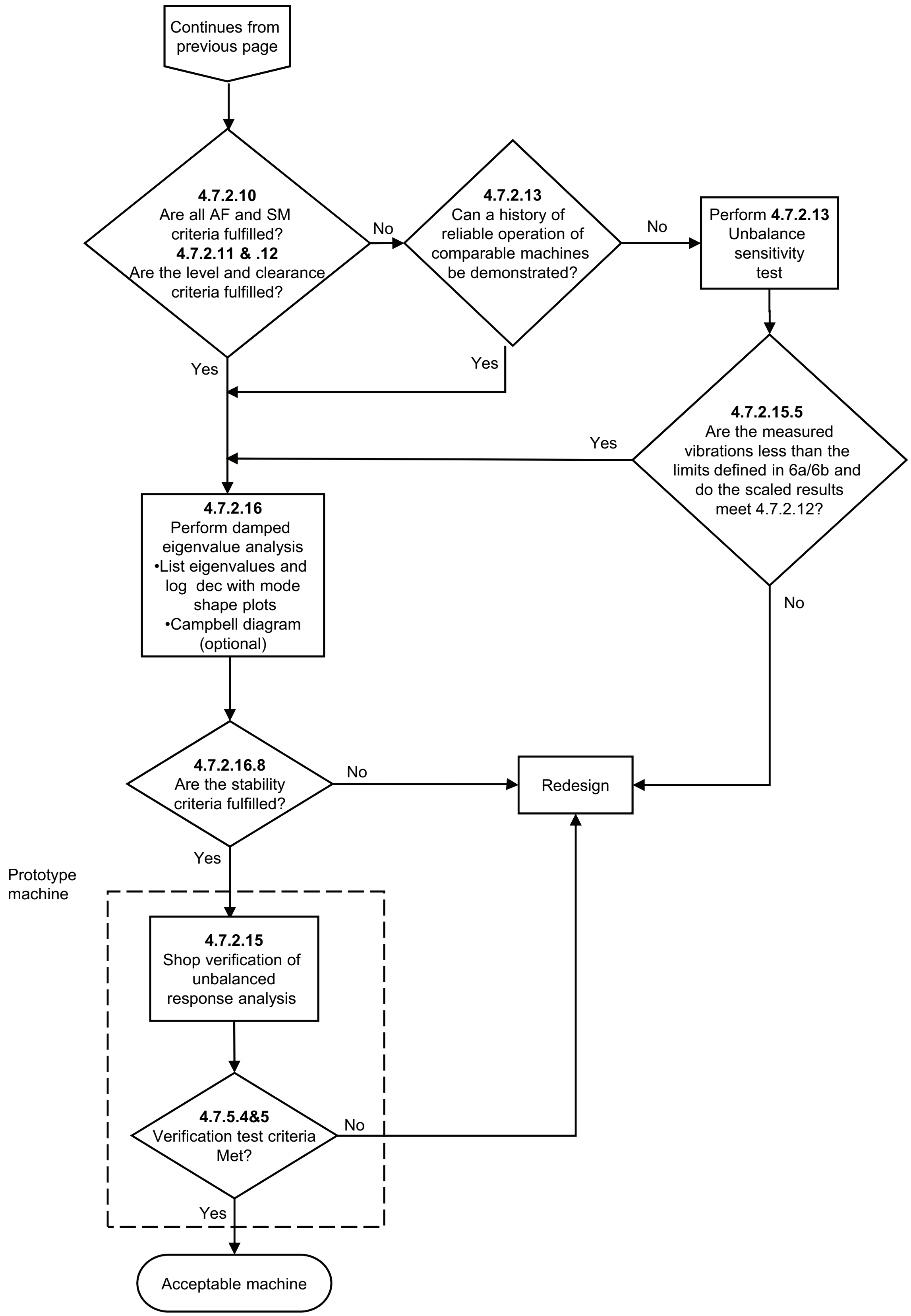


Figure D.2—Lateral Analysis Flowchart (continued)

Annex E
(informative)

Gas Turbine Nomenclature

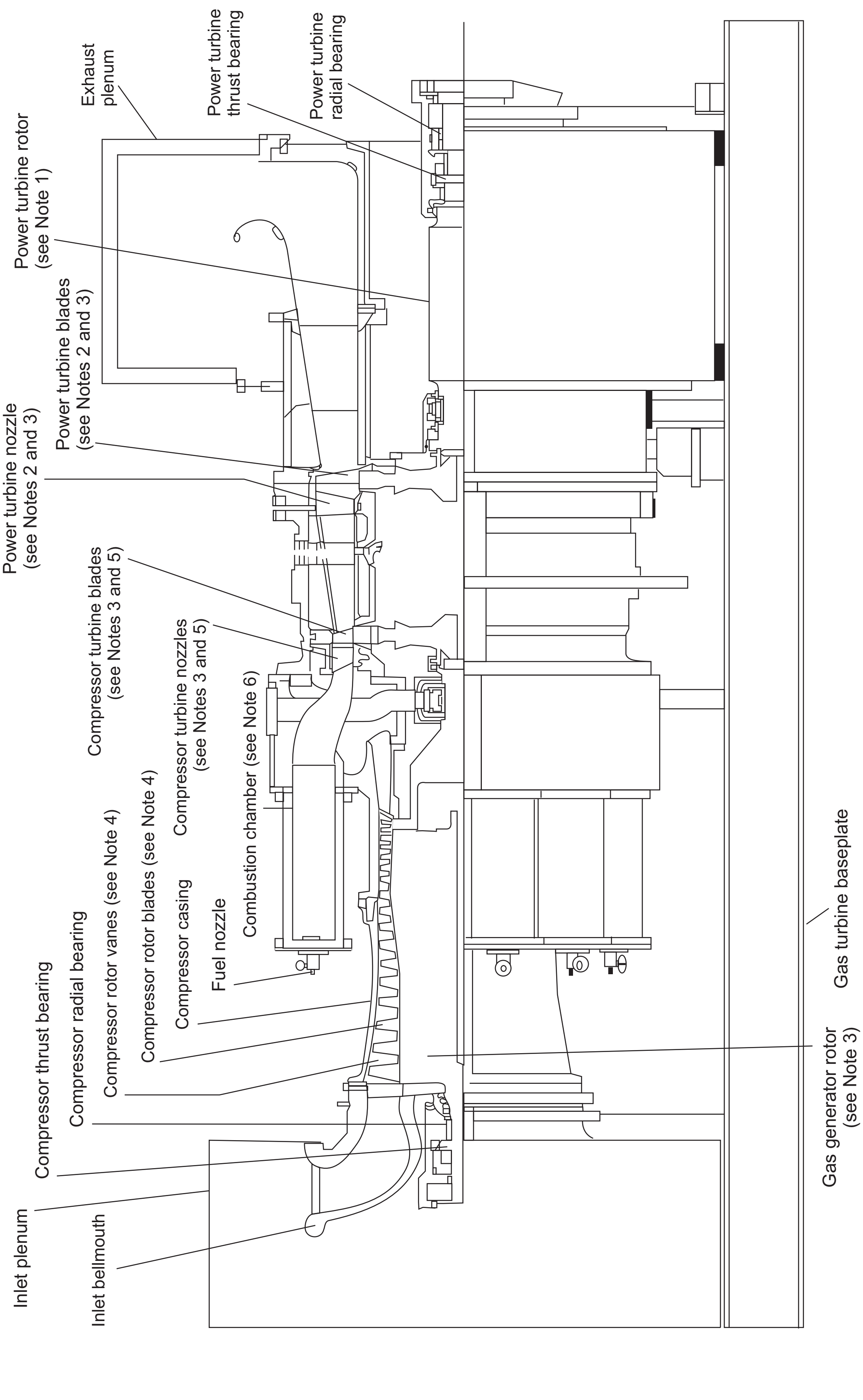


Figure E.1—Industrial Gas Turbine Nomenclature

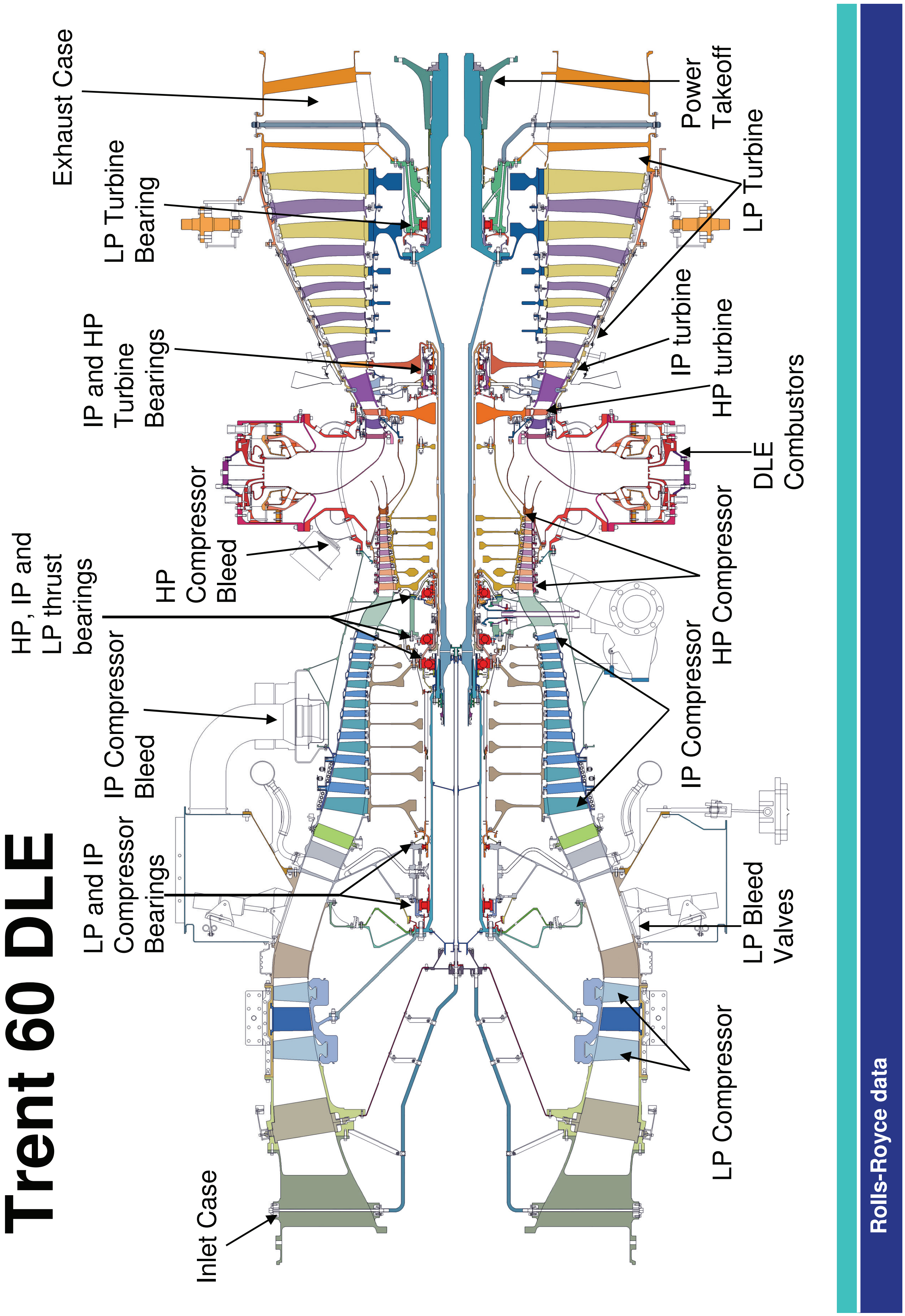
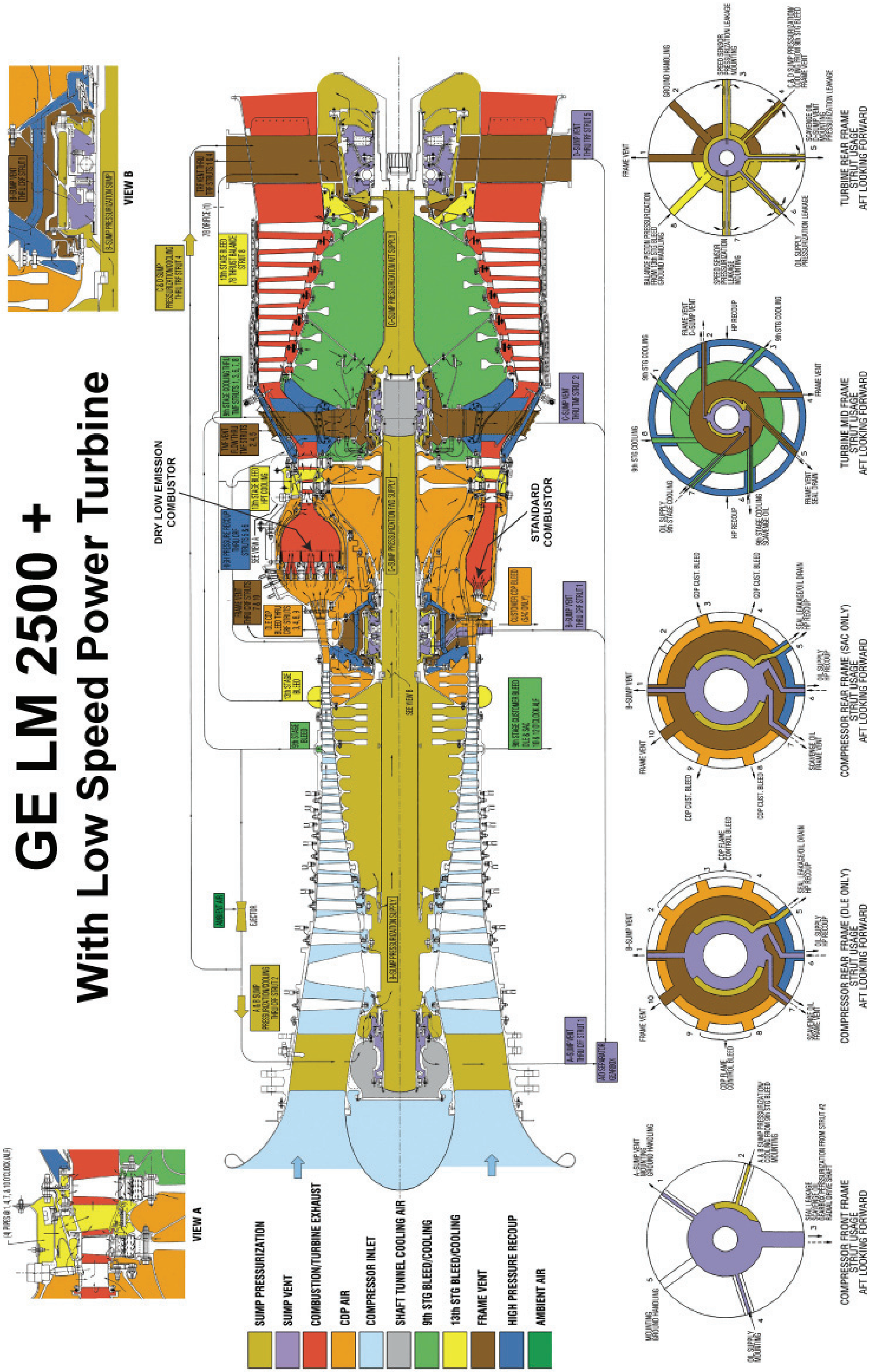


Figure E.2—Aeroderivative Gas Turbine Nomenclature



GE data

Figure E.3—Aeroderivative Gas Turbine Nomenclature energy API

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