

Gas Turbine

Specification

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

Technical Requirement: A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by imperative nature.

Recommended Practice: A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by verbs of a nonmandatory nature. It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "non-conformities" to this Standard that may contribute to the improvement thereof shall be submitted to the CONTEC - Authoring Subcommittee.

Proposed revisions to this Standard shall be submitted to the CONTEC - Authoring Subcommittee, indicating the alphanumeric identification and revision of the Standard, the section, subsection and enumerate to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

"This Standard is exclusive property of Petróleo Brasileiro S. A. - PETROBRAS, internal application and PETROBRAS Subsidiaries and shall be used by its suppliers of goods and services under contracts or similar under the conditions established in Bidding, Contract, Agreement or similar.

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CONTEC

Comissão de Normalização
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SC - 11

Machines

Introduction

PETROBRAS Technical Standards are prepared by Working Groups - WG (consisting specialized of Technical Collaborators from Company and its Subsidiaries), are commented by Company Units and its Subsidiaries, are approved by the Authoring Subcommittees - SCs (consisting of technicians from the same specialty, representing the various Company Units and its Subsidiaries), and ratified by the Executive Nucleus (consisting of representatives of the Company Units and its Subsidiaries). A PETROBRAS Technical Standard is subject to revision at any time by its Authoring Subcommittee and shall be reviewed every 5 years to be revalidated, revised or cancelled. PETROBRAS Technical Standards are prepared in accordance with PETROBRAS Technical Standard [N-1](#). For complete information about PETROBRAS Technical Standards see PETROBRAS Technical Standards Catalog.

Foreword

This Standard is the English version (issued in 11/2014) of PETROBRAS N-2922 12/2014. In case of doubt, the Portuguese version, which is the valid document for all intents and purposes, shall be used. This Standard is based on API [STD 616:2011](#) (Fifth Edition).

1 Scope

1.1 This Standard establishes the minimum conditions required for gas turbine and their auxiliary systems for refinery services, power generation plants, oil & gas production plants, compression and pumping stations and the like, to be supplied in accordance with API [STD 616:2011](#), Fifth Edition.

1.2 Gas turbine shall be in accordance with API [STD 616:2011](#), Fifth Edition, plus the following changes, as noted in parenthesis for each clause, according to the definitions stated below. The information of each clause shall be read as follows, whenever starting with:

- a) addition - continuation of that particular API [STD 616:2011](#) paragraph;
- b) modification - replacement of part of that affected API [STD 616:2011](#) paragraph;
- c) substitution - replacement of that API [STD 616:2011](#) paragraph in its entirety;
- d) new - insertion of a requirement not found in API [STD 616:2011](#);
- e) exclusion - removal of that particular API [STD 616:2011](#) paragraph.

1.3 Except for new items, item numbers referred in parentheses in this Standard are the same API [STD 616:2011](#), Fifth Edition paragraph ones.

1.4 PETROBRAS considers all items of API [STD 616:2011](#), other than those mentioned herein, as valid to this PETROBRAS Standard.

1.5 This Standard applies to design starting from its issue date.

1.6 This Standard contains only Technical Requirements.

2 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 applies.

CONAMA [436/2011](#) - Estabelece os limites máximos de emissão de poluentes atmosféricos para fontes fixas instaladas ou com pedido de licença de instalação anteriores a 02 de janeiro de 2007;

[NR-15](#) - Atividades e Operações Insalubres.

IEC [60034-1](#) - Rotating Electrical Machines – Part 1: Rating and Performance;

IEC [60079-29-1](#) - Explosive Atmospheres – Part 29-1: Gas Detectors – Performance Requirements of Detectors for Flammable Gases;

IEC [60079-29-2](#) - Explosive Atmospheres – Part 29-2: Gas Detectors – Selection, Installation, Use and Maintenance of Detectors for Flammable Gases and Oxygen;

IEC [61892-3](#) – Mobile and Fixed Offshore Units - Electrical Installations Part 3: Equipment;

ISO [7-1](#) - Pipe Threads Where Pressure-Tight Joints Are Made on the Threads - Part 1: Dimensions, Tolerances and Designation;

ISO [6183](#) - Fire Protection Equipment - Carbon Dioxide Extinguishing Systems for Use on Premises - Design and Installation;

ISO [7919-4](#) - Mechanical Vibration - Evaluation of Machine Vibration by Measurements on Rotating Shafts - Part 4: Gas Turbine Sets With Fluid-Film Bearings;

ISO 10438 - Petroleum, Petrochemical and Natural Gas Industries - Lubrication, Shaft-Sealing and Control-Oil Systems and Auxiliaries - Parts [1](#), [2](#), [3](#) and [4](#);

ISO [10441](#) - Petroleum, Petrochemical and Natural Gas Industries - Flexible Couplings for Mechanical Power Transmission - Special-Purpose Applications;

ISO [10816-4](#) - Mechanical Vibration - Evaluation of Machine Vibration by Measurements on Non-Rotating Parts - Part 4: Gas Turbine Sets With Fluid-Film Bearings;

ISO [11342](#) - Mechanical Vibration - Methods and Criteria for the Mechanical Balancing of Flexible Rotors;

ISO [TR 13387-7](#) - Fire Safety Engineering - Part 7: Detection, Activation and Suppression;

ISO 14520 - Gaseous Fire-Extinguishing Systems - Physical Properties and System Design;

API [STD 541](#) - Form-Wound Squirrel-Cage Induction Motors - 500 Horsepower and Larger;

API [STD 546](#) - Brushless Synchronous Machines - 500 kVA and Larger;

API [STD 613](#) - Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services;

API [STD 614](#) - Lubrication, Shaft-sealing and Oil-Control Systems and Auxiliaries;

API [STD 616:2011](#) - Gas Turbines for the Petroleum, Chemical, and Gas Industry Services;

API [STD 670](#) - Machinery Protection Systems;

API [STD 671](#) - Special-Purpose Couplings for Petroleum, Chemical, and Gas Industry Services;

ASTM [B841](#) – Standard Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits;

ASTM [B849](#) – Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement;

ASTM [B850](#) – Standard Guide for Post-Coating Treatments of Steel for Reducing Risk of Hydrogen Embrittlement;

ASTM [D1655](#) - Standard Specification for Aviation Turbine Fuels;

ASTM [D2880](#) - Standard Specification for Gas Turbine Fuel Oils;

BSI BS [EN 779](#) – Particulate Air Filters for General Ventilation - Determination of the Filtration Performance;

BSI BS [EN 13779](#) – Ventilation for Non-Residential Buildings - Performance Requirements for Ventilation and Room-Conditioning Systems;

NFPA [12](#) - Standard on Carbon Dioxide Extinguishing Systems;

NFPA [72](#) - National Fire Alarm and Signaling Code;

NFPA [750](#) - Standard on Water Mist Fire Protection Systems;

NFPA [2001](#) – Standard on Clean Agent Fire Extinguishing Systems;

NRC NEC CHANGES - National Energy Code of Canada for Building.

NOTE For documents referred in this Standard and for which only the Portuguese version is available, the PETROBRAS department that uses this Standard should be consulted for any information required for the specific application.

3 Terms and Definitions (Section 3 of API [STD 616:2011](#))

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

3.1 New (3.66 of API [STD 616:2011](#))

FPU

Floating Production Unit

3.2 New (3.67 of API [STD 616:2011](#))

certified point

point specified by purchaser at which the vendor certifies that the power and heat rate are within the tolerances stated in this standard. (see 4.2 of this Standard)

3.3 New (3.68 of API [STD 616:2011](#))

string test

complete unit test combined with the performance test

4 Basic Design

4.1 Modification (4.1.3 of API [STD 616:2011](#))

The purchaser shall specify the equipment's operating points on the datasheet (see 3.31 of API [STD 616:2011](#) and Annex A of this standard).

4.2 Modification (4.1.3.1 of API [STD 616:2011](#))

The gas turbine vendor shall guarantee turbine power (with no negative tolerance) at certified point condition as shown on the datasheet with a 3 % tolerance on the heat rate (lower heating value).

4.3 Modification (4.1.7 of API [STD 616:2011](#))

The gas turbine design shall accommodate transient thermal gradients following trip-outs 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. Any hot-start restriction shall be avoided through the use of an automatic turning gear device as described in item 4.17 (5.1.3.1 of API [STD 616:2011](#)) of this standard.

4.4 Addition (4.1.21 of API STD 616:2011)

If the site rated conditions (see 3.52 of API STD 616:2011) are not specified by contractor, vendor shall consider site maximum temperature, site minimum barometric pressure and site minimum relative humidity.

4.5 Modification (4.5.3.4 of API STD 616:2011)

Vendor shall include with the proposal the Campbell and Goodman diagrams for the blading backed demonstrating their adequacy to the project. The vendor shall indicate on the Goodman diagrams the standard acceptance margins.

4.6 Addition (4.6.1 of API STD 616:2011)

NOTE Vendor shall include with tender documents a complete sealing system description and material specifications for purchaser review.

4.7 Addition (4.7.2.3 of API STD 616:2011)

NOTE Vendor shall include with tender documents the Critical speed-support stiffness map.

4.8 Substitution (4.7.2.6 of API STD 616:2011)

In case of machine trains with rigid couplings, the vendor shall submit a train lateral analysis as per contract. This document shall be approved by the purchaser before the functional tests.

4.9 Acceptance Criteria - Substitution (4.7.5.2.1 of API STD 616:2011)

Acceptance criteria, for both new and overhauled machines, are based on shaft vibration, bearing housing vibration and on casing vibration. These criteria shall be applied during all the factory acceptance tests (e.g.: mechanical running test, performance test, complete unit test). 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 of API STD 616:2011), the vibration shall not exceed the following values:

a) shaft relative vibration is as follows: $A_{(\rho - \rho)}$ for Zone A in ISO 7919-4:

— in SI units: $A_{(\rho - \rho)} = 4800 / \sqrt{N} \mu m$ (10a)

— in USC units: $A_{(\rho - \rho)} = 190 / \sqrt{N} mils$ (10b)

— or 50 % of the manufacturer's published alarm set point value, whichever is lower, 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, or 50% of the manufacturer's published alarm set point value, whichever is lower;

c) during all the factory acceptance tests (e.g.: mechanical running test, performance test, complete unit test) for aircraft derivative gas generator/gas turbine, at any steady state speed within the operational range, the amplitude of vibration (measured at the manufacturer's standard sensor locations) shall not exceed 50 % of the manufacturer's published alarm set point value. This limit shall be based on filtered or unfiltered vibration data as per published in the project and shall be verified during the factory tests.

4.10 Modification (4.7.5.2.2 of API STD 616:2011)

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 and 1,5 mm/s (0,06 in/s) for bearing housing or casing vibration above the maximum value recorded at the maximum continuous speed.

NOTE These limits must not to be confused with the limits specified in 4.7.2.15 of API STD 616:2011 for shop verification of unbalanced response.

4.11 New (4.7.5.2.6 of API STD 616:2011)

At any speed, nonsynchronous filtered vibration shall not exceed 20 % of the synchronous vibration magnitude.

4.12 Acceptance Limits During Commissioning - Modification (4.7.5.3.1 of API STD 616:2011)

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

a) shaft relative vibration:

$$\text{— in SI units: } A_{(\rho - \rho)} = 7000 / \sqrt{N} \mu\text{m} \quad (11a)$$

$$\text{— in USC units: } A_{(\rho - \rho)} = 275 / \sqrt{N} \text{mils} \quad (11b)$$

— or 70 % of the manufacturer's published alarm set point value, whichever is lower, Where:

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

N is the maximum continuous speed in revolutions per minute.

- b) bearing housing or casing vibration: 6,5 mm/s (0,25 in/s) RMS, broadband or 70 % of the manufacturer's published alarm set point value, whichever is lower. 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.
- c) during field acceptance tests for aircraft derivative gas generator/gas turbine, at any steady state speed within the specified operating range, the amplitude of vibration (measured at the manufacturer's standard sensor locations) shall not exceed 70 % of the manufacturer's published alarm set point value.

4.13 New (4.7.5.4 of API STD 616:2011)

The vibration limits at factory and commissioning test during transient operation (start up or coast down), measured on shaft, bearing housing or casing, shall not exceed two times the limits for steady state operation, as specified in items 4.9 and 4.12 of this Standard.

4.14 Modification (4.10.1.2 of API STD 616:2011)

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 and coating material which does not have at least 16 000 hours total experience (of which 8 000 hours shall be continuous in one machine) at the same component shall be identified in the proposal, including a reference list.

4.15 Addition (4.10.1.5 of API [STD 616:2011](#))

For saline environments, bolts, nuts and other minor non painted carbon steel components shall be coated with Zinc-Nickel according to ASTM [B841](#), class 1, type B/E, grade 5 to 8, with stress and hydrogen relief treatment, according to ASTM [B849](#) and ASTM [B850](#). Alternatives may be offered and shall be agreed between purchaser and vendor.

4.16 Modification (4.10.2.3.3 of API [STD 616:2011](#))

All repairs shall be approved by the purchaser.

4.17 Modification (5.1.3.1 of API [STD 616:2011](#))

A turning gear device shall be furnished, if required to avoid rotor deformation after a trip-out. The turning gear operation shall be with automatic engagement/disengagement.

The gas turbine shall be able to restart at any time after an indeterminate period of time without external AC power supply. Purchaser will not guarantee any facility during time without AC power.

4.18 Modification (5.3.1.2.9 of API [STD 616:2011](#))

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

4.19 Modification (5.4.1.1 of API [STD 616:2011](#))

Instrumentation and installation shall conform to the requirements of purchaser's specifications, API [STD 614](#) and ISO 10438.

4.20 Modification (5.4.1.8 of API [STD 616:2011](#))

The control system shall be microprocessor based. The degree of redundancy shall be indicated in the data sheet.

4.21 Modification (5.4.4.7 of API [STD 616:2011](#))

Instrumentation, control devices, and annunciation display units shall be furnished, mounted and configured by the vendor.

4.22 Substitution (5.6.1.1 of API [STD 616:2011](#))

The gas turbine air intake system shall have at least the following components:

- inlet air filters;
- inlet silencer section;
- inlet plenum chamber;
- expansion joints;
- inlet ducting and interconnections;
- inlet instrumentation and related connection facilities;
- inlet electrical equipment and related connection facilities;
- access facilities including internal and external platforms, doors, walkways and ladders.

The gas turbine exhaust system shall have at least the following components:

- exhaust silencer section;
- exhaust plenum chamber;
- expansion joints;
- exhaust supports and steel work;
- insulation;
- instrumentation and related connection facilities;
- duct work and exhaust stack.

4.23 Substitution (5.6.1.9 of API STD 616:2011)

The purchaser shall specify the air quality as required by 5.6.1.9.1 and 5.6.1.9.2 of API STD 616:2011. In the absence of any required information, both vendor and purchaser shall mutually agree on the presence of the respective contaminants in the gas turbine and gas turbine package design in order to comply with the specified parameters of: performance, operability, reliability, availability, overhaul intervals, maintenance costs, and emissions.

4.24 Modification (5.6.1.10 of API STD 616:2011)

The complete air filtration system, including the filter house, shall be supplied in unpainted 316L stainless steel. All welds and stiffeners shall be continuous to avoid crevice corrosion.

NOTA 1 Where there would be contact of stainless steel and hot dip galvanized steel or carbon steel, shall be provided protection to avoid galvanic corrosion.

NOTA 2 The house for mounting to the FPU structure shall be furnished with supporting points.

NOTA 3 All fixing elements (such as bolts, nuts, washers etc) shall be designed such that they not be loosen and fall into the inlet of the gas generator.

4.25 Modification (5.6.1.14 of API STD 616:2011)

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 bell mouth entrance.

4.26 Addition (5.6.2.1.3 of API STD 616:2011)

A drain system shall be provided to ensure that any water caught within the air intake (upstream and downstream of all filter stages) is immediately removed, preventing the risk of re-entrainment into the airstream. Drains shall be fabricated with flange termination. The drain trap shall not allow unfiltered air ingress, water or another contaminant in any air filter degradation condition.

4.27 Addition (5.6.2.1.4 of API STD 616:2011)

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. Local differential pressure indicators and transmitters shall be furnished for each filter stage and for the total filter unit. Differential pressure signals shall be indicated at the Gas Turbine control panel.

4.28 Substitution (5.6.2.1.8 of API STD 616:2011)

Implosion door device shall not be used.

4.29 Modification (5.6.2.1.9 of API [STD 616:2011](#))

Unless otherwise specified, the filter house shall be elevated with a minimum 4,6 m (15 ft) elevation from grade to the lowest part of the filter air entrance, but shall be below top of the turbine exhaust stack. 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.

4.30 New (5.6.2.1.12 of API [STD 616:2011](#))

The filter house roof shall be sloped to shed rainwater. Internal lighting shall comply with the area classification.

4.31 Substitution (5.6.2.3 of API [STD 616:2011](#))

High-velocity filter systems shall not be used.

4.32 Substitution (5.6.2.4.1 of API [STD 616:2011](#))

The low-velocity inlet filter system recommended configuration shall consist of four filter stages. The rain protection with the trash screen is considered as zero stage. The four stages consist of inertial separator, coalescer pre-filter, inertial separator and high efficiency filter. Pre-filter and high efficiency filter shall be separated, nested assembling is not acceptable.

4.33 Substitution (5.6.2.4.2 of API [STD 616:2011](#))

The first filter stage consists of inertial separator with horizontal vanes. For saline environments it shall be fabricated in AISI 316L stainless steel.

4.34 Substitution (5.6.2.4.3 of API [STD 616:2011](#))

The second filter stage consist of coalescing pocket type pre-filter, class F5 according to BS [EN 779](#). A holding frame concept made of AISI 316L stainless steel shall be designed to support the coalescing filter elements and shall be equipped with the fixing pieces and the anti-leaks gasket.

4.35 Substitution (5.6.2.4.4 of API [STD 616:2011](#))

The third filter stage consists of inertial separator with vertical vanes - mist eliminator / droplets eliminator / inertial separator, made of AISI 316L stainless steel to remove the potential salt particles and droplet that has been coalesced from the last filter stage. This separator will assure that no humidity (water with salt) go into the last filter stage.

4.36 New (5.6.2.4.5 of API [STD 616:2011](#))

The fourth filter stage consists of a high efficiency filter, class F9 according to BSI [BS EN 779](#)/ BSI [BS EN 13779](#), based on pleated media in a rigid plastic molded type V-CELL. Filter media shall be made of micro fiber glass, moisture resistance up to 100% RH. A holding frame shall be made of AISI 316L stainless steel, each frame shall be equipped with the fixing pieces and the anti-leaks gasket.

4.37 New (5.6.2.4.6 of API [STD 616:2011](#))

The minimum distance between the first stage (inertial separator with horizontal vanes) and the second filter stage (coalescing pocket type pre-filter) shall be at least 700 mm.