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Gas turbine applications — Requirements for power generation

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National foreword

This British Standard is the UK implementation of ISO 19859:2016.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 192, *Gas turbines*.

Introduction

This International Standard provides technical information to be used for the procurement of gas turbines and the associated gas turbine systems for power generation by a Purchaser from a Contractor.

It provides a basis for the submission of tenders in line with the different environmental and safety requirements. It also specifies, wherever possible, criteria to establish whether these are met.

It defines a standard framework for dealing with questions of fuel and other matters, such as the minimum information to be provided by both the Purchaser and the Contractor. It does not, however, purport to include all necessary information for a contract and each gas turbine installation should be considered in its entirety. Attention is drawn to the need for technical consultation between the Purchaser and the Contractor to ensure compatibility of equipment being supplied, particularly where the responsibility for supply may be divided.

Because of the very widely varying operating modes for gas turbines in practice, distinct categories of operating modes are specified with which a “standard” rating can be associated. These ratings are made on the basis of the ISO standard ambient reference conditions.

Gas turbine applications — Requirements for power generation

1 Scope

This International Standard specifies the minimum technical and documentation requirements for the evaluation and procurement of gas turbine systems for electrical power generation.

It applies to simple cycle and combined cycle gas turbines for both onshore and offshore applications, where applicable. It also applies to gas turbines used in cogeneration (see ISO 11086:1996, Annex B). Testing of the gas turbine in combination with a generator is included in the scope.

It is not applicable to gas turbines used for all types of propulsion including aircraft, mobile barges, floating production vessels and marine propulsion applications and microturbines.

This International Standard defines the requirements for gas turbine power generation from an international perspective based on the content of existing, recognized ISO and IEC standards to the greatest extent practical. Nonetheless, it is recognized that within the industry other codes or standards are used, some of which are included in the text of this International Standard. The use of other such codes and standards is permissible provided an appropriate and acceptable level of requirements, functional design and safety is achieved and agreement has been reached for their use between the Purchaser and Contractor and such use is suitably documented.

Consideration should be given to applying/using standards in the following hierarchical order: international; regional; national; local.

This International Standard identifies the requirements for both the Purchaser and Contractor attributable to the design and procurement of a gas turbine power generation package.

The defined requirements apply to the scope of supply, except where excluded, encompassing the following equipment and the associated selected options, located within the power generation package, (see 3.14), listed below:

— gas turbine package;

— load shaft coupling and clutch, as applicable;

— air inlet system;

— exhaust system;

— fuel equipment;

— control equipment;

— electrical equipment;

— additional auxiliary systems, including starting, lubrication, barring, compressor wash, pipework, drains and vents;

— fire and gas protection;

— cooling water equipment.

Where applicable to the integrity of the gas turbine package, the interface and applicable design requirements are included for equipment, utilities and supplies that interface with the power generation package.

The following equipment is excluded from the scope of supply, but references are included where required for interface or performance measurement:

— generator and auxiliary systems, except the module control option;

— steam turbine and auxiliary systems;

— equipment external to the power generation package.

Data sheets in Annex A of this International Standard are provided for defining requirements and exchanging information between the Purchaser and the Contractor.

The Purchaser fills in the data sheets for the tender and forwards them to the Contractor. The Contractor responds by completing the applicable data sheets for their tender.

Annex A identifies the different types of data sheets and how they are to be used.

Where the Contractor does not comply with a selected requirement of this International Standard, this is detailed as an exception, referencing the applicable clause and describing the deviation and any alternatives available in a document listing all the exceptions taken.

Where the text in this International Standard requests procedures and operating, maintenance and commissioning manual information or equipment that would require the disclosure/supply of proprietary information/equipment which the Contractor is not prepared to release, such exceptions are listed. Where this situation exists, the Contractor will be prepared to release appropriate personnel and equipment to undertake all the tasks that otherwise would be undertaken by the Purchaser.

A bullet ● at the beginning of a paragraph in the text of this International Standard indicates an optional requirement (see A.3).

2 Normative references

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

ISO 128-1, *Technical drawings — General principles of presentation — Part 1: Introduction and index*

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

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 2314:2009, *Gas turbines — Acceptance tests*

ISO 2409, *Paints and varnishes — Cross-cut test*

ISO 2533, *Standard Atmosphere*

ISO 2592, *Determination of flash and fire points — Cleveland open cup method*

ISO 2909, *Petroleum products — Calculation of viscosity index from kinematic viscosity*

ISO 2954, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity*

ISO 3016, *Petroleum products — Determination of pour point*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

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

ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

ISO 3746, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 3977-1, *Gas turbines — Procurement — Part 1: General introduction and definitions*

ISO 3977-3:2004, *Gas turbines — Procurement — Part 3: Design requirements*

ISO 3977-4:2002, *Gas turbines — Procurement — Part 4: Fuels and environment*

ISO 3977-8, *Gas turbines — Procurement — Part 8: Inspection, testing, installation and commissioning*

ISO 3977-9:1999, *Gas turbines — Procurement — Part 9: Reliability, availability, maintainability and safety*

ISO 4261, *Petroleum products — Fuels (class F) — Specifications of gas turbine fuels for industrial and marine applications*

ISO 4263-1, *Petroleum and related products — Determination of the ageing behaviour of inhibited oils and fluids — TOST test — Part 1: Procedure for mineral oils*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 4407, *Hydraulic fluid power — Fluid contamination — Determination of particulate contamination by the counting method using an optical microscope*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 6247, *Petroleum products — Determination of foaming characteristics of lubricating oils*

ISO 6336-1, *Calculation of load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors*

ISO 6743-5, *Lubricants, industrial oils and related products (class L) — Classification — Part 5: Family T (Turbines)*

ISO 6976, *Natural Gas — Calculation of Calorific Values, Density, and Relative Density and Wobbe Index from Composition*

ISO 7919-4:2009, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 4: Gas turbine sets with fluid-film bearings*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8501-2, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings*

ISO 8501-3, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 3: Preparation grades of welds, edges and other areas with surface imperfections*

ISO 8502 (all parts), *Preparation of steel substrates before application of paints and related products — Tests for the assessment of surface cleanliness*

ISO 8504-1, *Preparation of steel substrates before application of paints and related products — Surface preparation methods — Part 1: General principles*

ISO 9120, *Petroleum and related products — Determination of air-release properties of steam turbine and other oils — Impinger method*

ISO 9223, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation*

ISO 9614-1, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

ISO 9614-2, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning*

ISO 9951, *Measurement of gas flow in closed conduits — Turbine meters*

ISO 10380, *Pipework — Corrugated metal hoses and hose assemblies*

ISO 10396, *Stationary source emissions — Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems*

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

ISO 10494, *Gas turbines and gas turbine sets — Measurement of emitted airborne noise — Engineering/survey method*

ISO 10816-2, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

ISO 10816-3, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ*

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

ISO 10817-1, *Rotating shaft vibration measuring systems — Part 1: Relative and absolute sensing of radial vibration*

ISO 11042-1, *Gas turbines — Exhaust gas emission — Part 1: Measurement and evaluation*

ISO 11042-2, *Gas turbines — Exhaust gas emission — Part 2: Automated emission monitoring*

ISO 11086:1996, *Gas turbines — Vocabulary*

ISO 11204, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections*

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

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 12151-1, *Connections for hydraulic fluid power and general use — Hose fittings — Part 1: Hose fittings with ISO 8434-3 O-ring face seal ends*

ISO 12151-2, *Connections for hydraulic fluid power and general use — Hose fittings — Part 2: Hose fittings with ISO 8434-1 and ISO 8434-4 24° cone connector ends with O-rings*

ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 12944-4, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation*

ISO 13691, *Petroleum and natural gas industries — High-speed special-purpose gear units*

ISO 13938-1, *Textiles — Bursting properties of fabrics — Part 1: Hydraulic method for determination of bursting strength and bursting distension*

ISO 14122-1, *Safety of machinery — Permanent means of access to machinery — Part 1: Choice of fixed means of access between two levels*

ISO 14122-2:2001, *Safety of machinery — Permanent means of access to machinery — Part 2: Working platforms and walkways*

ISO 14122-3, *Safety of Machinery — Permanent Means of Access to Machinery — Part 3: Stairs, Stepladders and Guard-Rails*

ISO 14122-4, *Safety of machinery — Permanent means of access to machinery — Part 4: Fixed ladders*

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

ISO 14691, *Petroleum, petrochemical and natural gas industries — Flexible couplings for mechanical power transmission — General-purpose applications*

ISO 14713-2, *Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures — Part 2: Hot dip galvanizing*

ISO 15649, *Petroleum and natural gas industries — Piping*

ISO 16276-2, *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating — Part 2: Cross-cut testing and X-cut testing*

ISO 18752, *Rubber hoses and hose assemblies — Wire- or textile-reinforced single-pressure types for hydraulic applications — Specification*

ISO 19840, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

ISO 19860:2005, *Gas turbines — Data acquisition and trend monitoring system requirements for gas turbine installations*

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

ISO 21940-13, *Mechanical vibration — Rotor balancing — Part 13: Criteria and safeguards for the in-situ balancing of medium and large rotors*

ISO 21940-31, *Mechanical vibration — Rotor balancing — Part 31: Susceptibility and sensitivity of machines to unbalance*

ISO 21940-32, *Mechanical vibration — Rotor balancing — Part 32: Shaft and fitment key convention*

ISO 22266-1, *Mechanical vibration — Torsional vibration of rotating machinery — Part 1: Land-based steam and gas turbine generator sets in excess of 50 MW*

ISO 80000-1, *Quantities and units — Part 1: General*

IEC 60034-1, *Rotating electrical machines — Part 1 — General requirements*

IEC 60034-3:2010, *Rotating electrical machines — Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines*

IEC 60034-5, *Rotating electrical machines — Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) — Classification — Edition 4.1; Consolidated Reprint*

IEC 60038:2009, *EC standard voltages*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-11, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-14:2013, *Electrical installations in hazardous areas (other than mines)*

IEC 60146-1, *Semiconductor converters — General requirements and line commutated converters — Part 1-1: Specification of basic requirements*

IEC 60204-1:2009, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60204-11, *Safety of machinery — Electrical equipment of machines — Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60304, *Standard Colours for Insulation for Low-Frequency Cables and Wires*

IEC 60332, *Tests on electric and optical fibre cables under fire conditions: Relevant Part*

IEC 60364-1, *Low-voltage electrical installations — Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41, *Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock*

IEC 60417, *Graphical symbols for use on equipment*

IEC 60439, *Low-Voltage Switchgear and Control gear Assemblies: Relevant parts*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals, conductor terminations and conductor*

IEC 60502, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV): Relevant Parts*

IEC 60529:2013, *Degrees of Protection Provided by Enclosures (IP Code)*

IEC 60757, *Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals, conductor terminations and conductor*

IEC 60896, *Stationary lead-acid batteries: Relevant Parts*

IEC 60947, *Low-voltage switchgear and control gear — Relevant parts*

IEC 60947-7-1, *Low-voltage switchgear and control gear — Part 7-1: Ancillary equipment — Terminal blocks for copper conductors*

IEC 61000-2-2, *Electromagnetic Compatibility (EMC) Part 2-2: Environment — Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Public Low-Voltage Power Supply Systems*

IEC 61000-2-4:2002, *Electromagnetic compatibility (EMC) Part 2-4: Environment Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) — Part 6-3: Generic standards — Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments*

IEC/TR 61000-5-1, *Protection against lightning — Part 1: General principles*

IEC/TR 61000-5-2, *Electromagnetic Compatibility (EMC) — Part 5: Installation and Mitigation Guidelines — Section 2: Earthing and Cabling*

IEC 61140, *Protection against electric shock — Common aspects for installation and equipment*

IEC 61643-12, *Low-voltage surge protective devices — Part 12: Surge protective devices connected to low-voltage power distribution systems — Selection and application principles*

IEC 61672-1, *Electroacoustics — Sound Level Meters — Part 1: Specifications*

IEC 61786, *Measurement of Low-Frequency Magnetic and Electric Fields with Regard to Exposure of Human Beings — Special Requirements for Instruments and Guidance for Measurements*

IEC 61918, *Industrial communication networks — Installation of communication networks in industrial premises*

IEC 61936-1, *Power installations exceeding 1 kV a.c. — Part 1: Common rule*

IEC 62040-1, *Uninterruptible power systems (UPS) — Part 1: General and safety requirements for UPS*

IEC 62040-2, *Uninterruptible power systems (UPS) — Part 2: Electromagnetic compatibility (EMC) requirements*

IEC 62305-1, *Protection against lightning — Part 1: General principles*

IEC 62305-4, *Protection against lightning — Part 4: Electrical and electronic systems within structures*

IEC 82079-1, *Preparation of instructions for use — Structuring, content and presentation — Part 1: General principles and detailed requirements*

EN 779, *Particulate air filters for general ventilation — Determination of the filtration performance*

EN 1822-1, *High efficiency air filters (EPA, HEPA and ULPA) — Part 1: Classification, performance testing, marking*

EN 1822-5, *High efficiency air filters (EPA, HEPA and ULPA) — Part 5: Determining the efficiency of filter elements*

EN 1837, *Safety of machinery — Integral lighting of machines*

EN 1838, *Lighting Applications — Emergency Lighting*

EN 1997-1, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 13284-1:2001, *Stationary Source Emissions — Determination of Low Range Mass Concentration of Dust — Part 1: Manual Gravimetric Method*

EN 13480-1, *Metallic industrial piping — Part 1: General*

EN 15259-1:2007, *Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report*

EN 50160, *Voltage characteristics of electricity supplied by public electricity networks*

EN 50272-2, *Safety Requirements for Secondary Batteries and Battery Installations Part 2: Stationary Batteries*

EN 50522, *Earthing of power installations exceeding 1 kV a.c*

IEEE C50.13, *Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above*

IEEE C95.3, *IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz–300 GHz*

IEEE 762:2006, *Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity*

AGMA 6011-I03, *Specification for High Speed Helical Gear Units*

AGMA 6011-J14, *Specification for High Speed Helical Gear Units*

AGMA 6123-B06, *Design Manual for Enclosed Epicyclic Gear Drives*

ASHRAE 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*

API 613, *Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services*

API 670, *Machinery Protection Systems*

ASME B31.1, *Power Piping*

ASME B31.3, *Process Piping*

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

ASTM D3786, *Standard Test Method for Bursting Strength of Textile Fabrics—Diaphragm Bursting Strength Tester Method*

NAS 1638, *Cleanliness requirements of parts used in hydraulic systems*

NEMA MG1, *Motors and Generators*

NFPA 70, *National Electrical Code*

NFPA 85:2015, *Boiler and Combustion Systems Hazards Code*

SAE AS 4059E, *Aerospace Fluid Power — Cleanliness Classification for Hydraulic Fluids*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3977-1, ISO 3977-3, ISO 3977-4:2002, ISO 3977-8, ISO 3977-9:1999, ISO 11086:1996 and the following apply.

3.1
auxiliary systems
interconnected electrical, control and mechanical equipment with specific functions relating to main items of equipment such as lubricating oil system, fuel system, controls and their external interconnections

3.2
combined cycle
thermodynamic cycle employing the combination of a gas turbine cycle with a steam or other fluid Rankine cycle

Note 1 to entry: In a common example, the gas turbine exhaust heat is used to generate steam for the Rankine cycle.

Note 2 to entry: The superior thermal performance of this cycle is due to a combination of the best thermodynamic attributes of each cycle, namely the addition of thermal energy at higher temperatures in the gas turbine cycle and the rejection of thermal energy at lower temperatures in the Rankine cycle.

[SOURCE: ISO 11086:1996, 1.12]

3.3
Contractor
organization for the supply of goods and/or services applicable to the specific clause(s) of this International Standard

3.4
enclosure
structure enveloping/enclosing sections of equipment for the applicable requirements of

— weather protection (all applicable types),

— noise attenuation,

— ventilation for removal of hazardous gases and vapours,

— ventilation for temperature control,

— control of radiated heat, and

— contamination due to local environment conditions.

3.5
gas turbine core
assembly that includes the gas turbine compressor, combustion system, power turbine and integral equipment

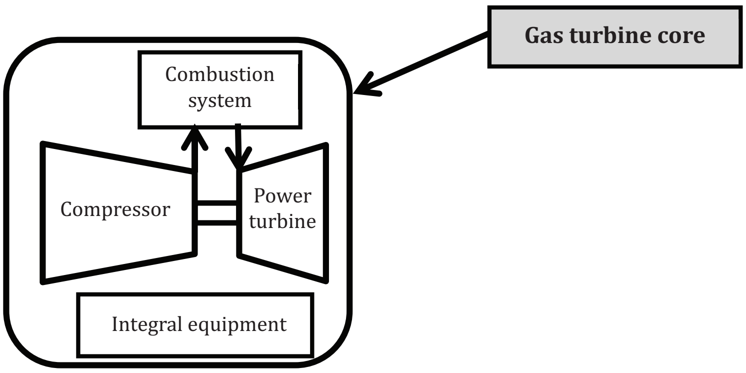

Figure 1 — Gas turbine core

3.6
gas turbine enclosure
local *enclosure* (3.4) covering a single gas turbine

3.7
gas turbine hall
large structure that may enclose one or more gas turbine packages, each of which may have their own local *enclosure(s)* (3.4)

3.8
gas turbine package
assembly that includes the *gas turbine core* (3.5), gas turbine load and auxiliary gearboxes, core integral equipment, applicable auxiliary systems and *enclosure* (3.4)

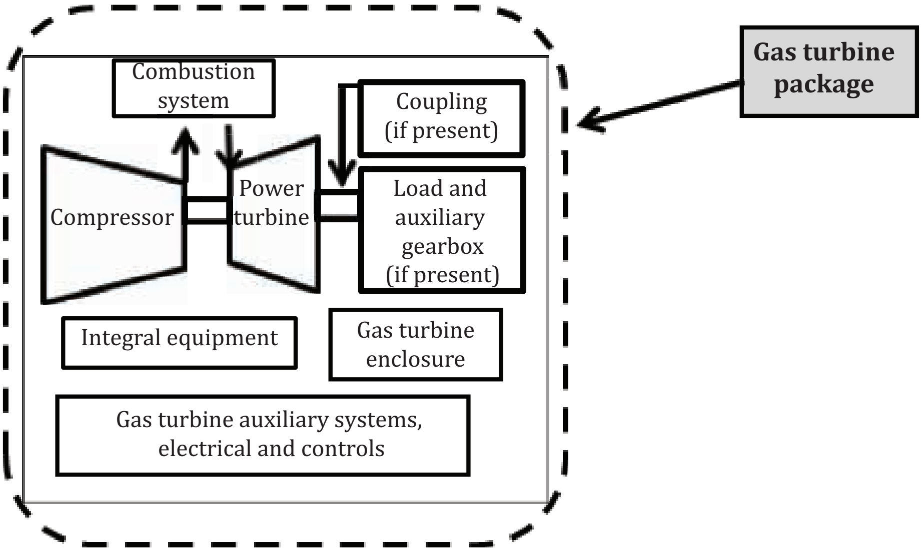

Figure 2 — Gas turbine package

3.9
Island mode
operation of one or more power generation packages operating independently when a local grid connection fails or is disconnected or as a standalone grid with one or more power generation packages supplying the local loads

3.10
lifed component
any component within the *gas turbine core* (3.5) with a shorter finite useable life than the design life of the gas turbine in terms of permitted starts, operating hours or weighted operating hours before action (e.g. inspection, repair or scrapping) is required

3.11
MCR
maximum continuous rating
maximum continuous electrical output for the power generation package with the *gas turbine package* (3.8) operating at its maximum reference turbine control temperature [exhaust temperature, *TIT* (3.27) or *RIT* (3.20)] and its inlet guide vanes (where fitted) fully open

3.12
MCO
minimum continuous rating
minimum continuous electrical output for the *power generation package* (3.14) without meeting emission limits and environmental constraints

3.13
MEL
minimum environmental load
minimum continuous electrical output for the *power generation package* (3.14) while meeting all emission limits and environmental constraints

3.14
power generation package
assembly that includes the *gas turbine package* (3.8), generator, steam turbine (if on the same shaft), inlet system, exhaust system as applicable, fuel system, controls and electrical equipment, auxiliaries and *enclosures* (3.4)

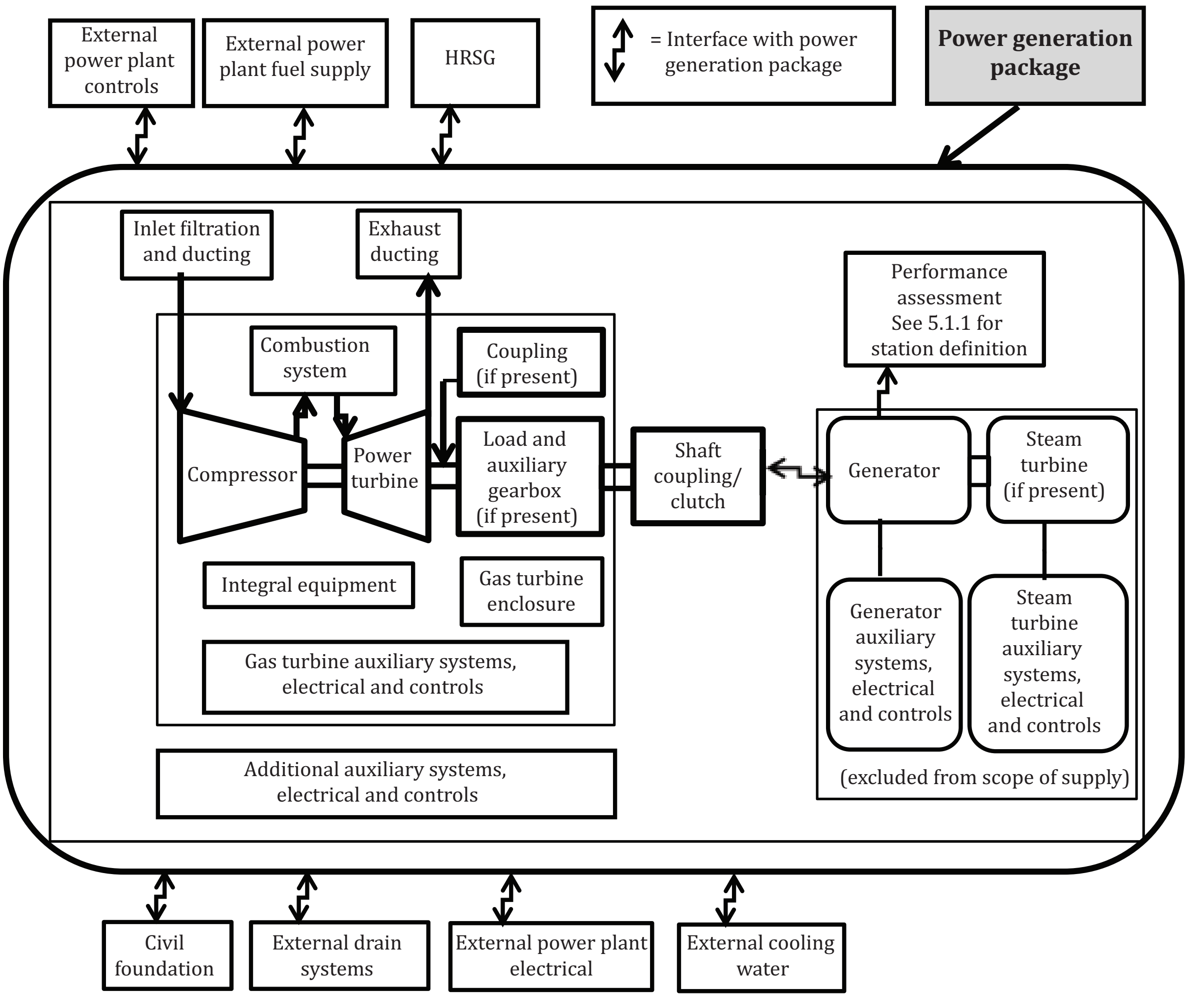

Figure 3 — Power generation package

3.15
power plant
all main equipment and auxiliary equipment employed in producing electrical power at a *site* (3.23) and may include one or more *power generation packages* (3.14)

3.16
power rating
net electrical power developed by the gas turbine when it is operated at a defined reference turbine control temperature [exhaust temperature, *TIT* (3.27) or *RIT* (3.20)] and standard reference conditions

3.17
project
general term for all the works and equipment for the construction of the concerned *power plant* (3.15)

3.18
Purchaser
person or company having authority to specify and to buy the equipment, who has a contract(s) with the *Contractor(s)* (3.3) and is considered to be the owner and operator of the *power plant* (3.15)

[SOURCE: ISO 21789:2009, 3.11, modified]

3.19
rated speed
speed expressed in revolutions per minute of the *gas turbine core* (3.5) output shaft required for generator synchronous speed

3.20
RIT
rotor inlet temperature
flow weighted mean total temperature of the working fluid relative to a stationary plane immediately upstream of the first rotating row of turbine blades

Note 1 to entry: Also known as the firing temperature.

3.21
sequential combustion
process created by a gas turbine that typically consists of two combustors, a high pressure combustor followed by a high pressure turbine and a low pressure combustor followed by a low pressure turbine

3.22
simple cycle
thermodynamic cycle consisting only of successive compression, combustion and expansion

[SOURCE: ISO 11086:1996, 1.8]

3.23
site
geographical location of the *power plant* (3.15)

3.24
site rated power
net electrical output developed by the gas turbine when it is operated at the applicable site reference turbine control temperature [exhaust temperature, *TIT* (3.27) or *RIT* (3.20)] at site rated conditions of speed, inlet temperature, inlet pressure, exhaust pressure and normal fuel composition

3.25
specification
Purchaser's (3.18) requirements in conjunction with the complete or fractional requirements of this International Standard

3.26
tender
document containing the contractual offer for the supply and installation of a *power plant* (3.15) provided by a *Contractor* (3.3) when requested by a *Purchaser* (3.18) during the procurement phase

3.27
TIT
turbine inlet temperature
mean temperature of the working fluid upstream of the first stage turbine stator blades

[SOURCE: ISO 2314:2009, 3.15, modified]

4 Comparative performance assessment at standard reference conditions

4.1 General

The power rating (see 3.16), heat rate and exhaust emissions required and fuel consumption shall be supplied at MEL, 50 % MCR and MCR for comparative performance assessment purposes at the initial enquiry stage. Ratings shall be based on the standard reference condition and given fuel values specified in 4.2.6, neglecting pressure drops at the inlet and exhaust systems and generator excitation energy. The details shall be supplied on the information data sheet by the Contractor for the fuel(s) selected thereon by the Purchaser.

Exhaust emissions [NO_X, CO, unburned hydrocarbons (UHC)] shall be quoted as gas/vapour emission concentrations reported on a dry basis (corrected to 15 % oxygen) for operation on fuels specified in 4.2.6. Sulfur emissions are solely a function of the sulfur present in the incoming air and fuel flows. Sulfur emissions are not to be stated since the gas turbine(s) has no influence on them.

4.2 Standard reference conditions

4.2.1 General

The standard reference conditions on which ISO power, efficiency, heat rate and specific fuel consumption are based are as specified in 4.2.2 to 4.2.5.

4.2.2 Ambient conditions

For the intake air at the compressor flange (alternatively, the compressor intake flare), in accordance with ISO 2533, the conditions shall be as follows:

— a total pressure of 101,325 kPa;

— a total temperature of 15 °C;

— a relative humidity of 60 %.

4.2.3 Exhaust conditions

For the exhaust at the turbine exhaust flange (or regenerator outlet, if a regenerative cycle is used), the static pressure shall be 101,325 kPa.

4.2.4 Cooling water conditions (if applicable)

Where a heater or a cooler is used that uses cooling water, the standard reference conditions for the temperature of the cooling water shall be 15 °C.

4.2.5 Working fluid heater or cooler

Where a heater or a cooler is used that uses ambient air, the standard reference conditions for the ambient air shall be 15 °C and 101,325 kPa.

4.2.6 Fuel for comparative performance assessment

For a comparative performance assessment, fuel details shall be based on the following:

— turbines intended for use on gaseous fuel: Natural gas 100 % methane – 50 035 kJ/kg;

— turbines intended for use on liquid fuel: No. 2 Distillate – 42 600 kJ/kg and a carbon to hydrogen weight ratio of 6 to 1.

The lower heating value (LHV) at constant pressure of the fuel(s), whether liquid or gaseous, is based on a pressure of 101,325 kPa and a temperature of 15 °C.

5 Performance at site conditions

5.1 Site rating

5.1.1 Site rated power

The contractual site rated power (see 3.24), fuel consumption and exhaust emissions shall be supplied (at the tender stage) at the MCR required as described in 4.1 based on the following conditions and requirements.

— The station definition in ISO 2314:2009, 6.4.5.1 Table 5 9.1a unless otherwise specified on the information data sheet.

— The specific site conditions as described in 5.2, including fuel details as described in Clause 8.

— Air inlet losses shall be based upon air inlet filters at new and clean values but using air velocities specific to the design of the air inlet house.

— Exhaust losses shall be based on the complete exhaust system whether for simple cycle or combined cycle or cogeneration plant.

— A new and clean gas turbine core. New is defined as the gas turbine core having nominally less than 200 fired operating hours. A clean gas turbine is defined as where the gas turbine core has operated nominally less than 25 h since an offline water wash.

— Emissions shall be quoted for NO_X, CO and UHC.

The output shall not include any degradation or ageing as defined by ISO 2314:2009, 3.1.

5.1.2 Site minimum load

The contractual site rated power at minimum load based on the applicable conditions defined for site rated power in 5.1.1 shall be specified for

— MEL, taking into account any emission controls downstream of the exhaust outlet flange, and

— MCO.

5.1.3 Site net heat rate

The contractual site net heat rate shall be specified based on the applicable conditions in 5.1.1 and computed in accordance with ISO 2314:2009, 8.1.3 for

— the site rated power at MCR as 5.1.1, and

— the site rated power at MEL as 5.1.2.

5.1.4 Site peak load

● If requested by the Purchaser, the peak load capability (as defined in ISO 3977-3:2004, 3.35) on the information data sheet and any implications shall be defined in accordance with the document data sheet.

5.2 Site conditions

The performance shall be quoted at the following site parameters and operating conditions, where applicable.

The site rated power shall be quoted at the following applicable site parameters and operating conditions, defined by the Purchaser.

— Ambient temperature (°C).

— Barometric pressure [Pa and (bar)].

— Ambient relative humidity (%).

— Contract gas fuel details (see Clause 8).

— Contract liquid fuel details (see Clause 8).

— Load gearbox efficiency, where applicable and supplied by the Purchaser.

— Generator efficiency where supplied by the Purchaser, taking into account all losses, at each load condition, and cooling media requirements/conditions.

— Generator speed at nominal grid frequency.

— Generator voltage.

— Generator nominal power factor, leading or lagging, at the grid frequency, where supplied by the Purchaser.

— Inlet conditioning, where applicable and supplied by the Purchaser.

— Exhaust back pressure, where applicable (see 21.7).

5.3 Corrections

Corrections from the Contractor's design values to the contractual ratings shall follow the guidance in ISO 2314:2009 or as otherwise specified by the Purchaser in accordance with the document data sheet.

6 Site conditions and utilities

6.1 Air quality

The Purchaser shall provide the following information on the information data sheet.

— Sufficient information to determine the local air quality to enable the Contractor to properly design the air inlet filtration system and determine the impact of the air quality on the lifetime of the gas turbine package equipment.

— Where potentially significant air contamination is present, data of specific measurements of the local air quality over a sufficient period of time by air sampling to establish representative information of dust, dirt and other contaminants of the combustion air.

— Classification of the corrosivity of the atmosphere in accordance with ISO 9223.

— Details of any rural, agricultural, commercial, urban, light and heavy industrial local sources of airborne emissions.

— Sources of dust emissions such as adjacent coal storage, gypsum or similar manufacturing plants, construction and quarrying activities.

The Purchaser shall provide the following information on the document data sheet:

— Site map and the typical wind direction commonly issued as a wind rose showing direction velocity and direction likelihood.

— Details of conditions where hot, dust bearing winds may be present (e.g. Sirocco or equivalent).

Sampling shall be supplemented by analysis of the composition of materials to identify contaminants. This also helps to identify sources of contaminants such as salt and fouling sources such as road/rail transport.

Due consideration should be taken by the Purchaser of any known future plans that could impact air quality.

The predominant soil type composition may have a specific impact on air quality and air filter type and grade. The gas turbine hot gas path Thermal Barrier Coatings (TBC) can be affected by contamination by basic elements within soils such as Ca, Mg, Al and SiO_2 and is collectively referred to as CMAS contamination. This contamination results in the premature spalling of this coating with impacts on component life and repair yield. Hot, dry climates are at greater risk of having higher dust concentrations in the air.

6.2 Water quality

The Purchaser shall define the following:

— potable water quality available;

— potable water flow capacity;

— water quality available for cooling water;

— cooling water supply pressure, temperature and flow capacity and any limitations on the return flows;

— quality of demineralized water available;

— demineralized water supply pressure, temperature and flow capacity.

The Contractor shall document the water requirement (supply pressure, temperature and flow) against each applicable usage and the required water quality for all water types in accordance with the document data sheet.

6.3 Steam quality

The Purchaser shall define the following:

— steam quality available;

— steam pressure, temperature and flow capacity available.

The Contractor shall document the steam requirement (supply pressure, temperature and flow and return flow if any) against each applicable usage and the required steam quality in accordance with the document data sheet.

6.4 Purge media quality

The Purchaser shall define the following:

— plant and instrument air pressure and flow capacity available;

— nitrogen supply pressure and storage capacity.

The Contractor shall document the purge media requirement (media type, supply pressure, temperature and flow) against each applicable usage for each start-up and shutdown cycle and the required purge media quality in accordance with the document data sheet.

6.5 Interface and utility connection points

The Purchaser shall document, in accordance with the document data sheet, the interface, termination and utility connection details and locations in a qualitative and quantitative manner for all applicable interfaces between the proposed power generation package location and connecting equipment or utilities. Connecting equipment is listed in the Scope (Clause 1) and utilities that may be applicable include, but are not limited to, the following:

- fuel supply termination point(s);
- junction box(es) for control and instrumentation (C&I) signals to/from the gas inlet location/reception compound and generating unit control room;
- electrical supply termination(s) in a distribution board located outside the gas inlet location/reception compound boundary fence;
- access road to gas inlet location/reception compound;
- isolating valve for local municipal authority or potable water supplier;
- cooling water or process water source and any existing structure for take-off;
- demineralized water supply;
- steam supply;
- plant air supply;
- instrument air supply;
- nitrogen purge supply;
- isolating valve for local municipal authority or water supplier responsible for foul water removal;
- surface water drainage destination and any existing structure for collection;
- oily water drainage destination and any existing structures for collection;
- generator connection to the grid organization's busbars;
- voltage transformers (VT) and current transformers (CTs) connected to outgoing terminals of interface termination cubicle;
- earth pillar location for each connection;
- nearest existing access road – general traffic;
- nearest existing access road – construction traffic;
- location of telephone company lines.

The Purchaser is responsible for the organization, coordination and information exchange methodologies between Contractors supplying equipment to the site.

The Contractor shall document the location and details of all the applicable interface connection points listed above in the Contractor's scope of supply in accordance with the document data sheet.

6.6 Gas turbine orientation due to site conditions

The Contractor shall arrange, following the receipt of the project information (including the prevailing wind direction), for the gas turbine package and its air intake to be orientated within the constraints of the available plot so that the gas turbine package's exposure to airborne contaminants is minimized and the impact of other equipment is considered.

The Purchaser shall advise the location of any existing or proposed cooling towers or other known equipment that may impact gas turbine package performance or air quality in accordance with the document data sheet.

7 Discharges and emissions to the environment

7.1 General

Environmental issues primarily include emissions during start-up, shutdown and general operation. Typical emissions of interest are noise (acoustic), combustion-generated emissions, waste fluids, mists, vents and thermal emissions. These topics are described in 7.2 to 7.8.

Toxic and/or hazardous emissions shall be prevented in accordance with ISO 21789:2009, 5.22.3.

7.2 Design philosophy for prevention of unplanned release of fluids

The Contractor shall document the full inventory of fluids within the gas turbine package and its auxiliary systems and containment methods that would prevent unacceptable release of these fluids in accordance with the document data sheet. The Contractor shall design these containment systems to prevent a release to the environment based upon credible failure scenarios for storage and pipework systems. The Contractor shall provide functional requirements for detailed design of containment systems (e.g. bunding) not included in the Contractor's scope of supply in accordance with the document data sheet.

7.3 Noise emissions

7.3.1 General

The Purchaser shall specify on the information data sheet the allowable sound pressure level acceptable for major equipment, blow offs and vents that generate a significant noise level, where applicable, including, but not limited to, the following:

— gas turbine air inlet;

— gas turbine enclosure;

— gas turbine exhaust;

— reduction gearboxes.

● If requested by the Purchaser, the Contractor shall provide the predicted or measured sound pressure and sound power level noise spectrum for the said equipment and the peak predicted or measured sound levels from blow offs and vents (see 33.4).

● If requested by the Purchaser, near field noise levels shall be measured by the Contractor.

For personnel protection the requirements of ISO 21789:2009, 5.7 shall be applied.

7.3.2 Methods for sound measurements and predictions

Sound pressure levels shall be measured in accordance with ISO 10494 and ISO 11204 for workstations.

● If requested by the Purchaser, sound power levels shall be measured in accordance with ISO 9614-1 or ISO 9614-2.

Nominal far field noise predictions may be undertaken in accordance with ISO 9613-2 utilizing information provided under 7.3.1.

7.3.3 Sound level within the gas turbine enclosure

● If requested by the Purchaser, the Contractor shall provide estimated sound levels inside the gas turbine enclosure. Where measurements have been undertaken, these shall be made in accordance with ISO 3746. If the enclosure is not accessible during running, this requirement may be waived.

7.4 Exhaust emissions

7.4.1 General

The height of exhaust outlets, where applicable, shall be sufficient to provide adequate dispersion of all emissions and the design shall take into account the potential, under reasonably foreseeable operating conditions, for large amounts of oxygen depleted air, carbon monoxide or other hazardous air pollutants being emitted that can cause the asphyxiation of personnel in the area of an inadequately dispersed exhaust. The emissions shall not cause a danger to nearby persons or property.

NOTE Regional, national or local regulations can govern stack heights.

7.4.2 Responsibilities

The Purchaser shall specify the specific emission levels to be achieved over the required load range and any relevant environmental regulations and restrictions existing or being developed that are applicable to the project for a specific fuel composition in accordance with the document data sheet.

The Contractor shall be responsible for the gas turbine package performing according to the exhaust emission levels defined by the Purchaser. The exhaust gas emission levels apply for gas turbine operation with the specific fuel and specified air quality at the specific site ambient conditions (pressure, temperature and relative humidity) as advised by the Purchaser.

See also Clause 8 for contract fuels.

7.4.3 Reporting emissions

The Contractor shall provide emission levels information, at MCR for applicable fuels, for the following:

— NO_X;

— CO.

● If requested by the Purchaser, the Contractor shall provide emission levels information, at MCR, for the following:

— unburned hydrocarbons (UHC);

— volatile organic compounds (VOC) (gas);

— smoke opacity or visibility;

— particulates (total including condensable).

● If requested by the Purchaser, the Contractor shall provide the same emission levels information as provided at MCR for the following load conditions:

— MCO;

— MEL;

— other values as specified by the Purchaser.

The definition of UHC and VOC shall be in accordance with ISO 11042-1. Additionally, the composition of the exhaust gases (such as CO_2, H_2O, O_2, N_2, argon) shall be known (both on a volumetric and mass basis) since this information may be required for any post-combustion equipment.

The methods used for the measurement, analysis and evaluation shall be in accordance with ISO 11042-1 or ISO 11042-2, or applicable regional, national or local regulatory authority requirements or standards. Reporting values and particulate details are described in ISO 3977-4:2002, 6.3.3 and 6.3.5. When reporting emissions on a density basis, the reference temperature and pressure shall be clearly specified.

7.4.4 Start-up emissions

● If requested by the Purchaser, the Contractor shall provide a prediction of the start-up emissions from ignition to full load for NO_X and CO for all start conditions (cold, warm and hot starts as applicable) and fuels.

7.5 Post-combustion controls

The impact of post-combustion controls on all emissions is important. For example, oxidation catalysts shall oxidize fuel sulfur to SO_3, and may potentially increase the total particulate emission. Selective catalyst reducers (SCR) can further increase particulate emissions via the formation of ammonium sulfates and ammonia slip. The Purchaser shall be aware of the interaction between any proposed post-combustion controls technology and gas turbine package emission levels. It is the responsibility of the Purchaser to evaluate the impact of all post-combustion control technologies on the exhaust emission signature.

7.6 Emission monitoring

● If requested by the Purchaser, the Contractor shall supply equipment for continuous monitoring of exhaust emissions according to the requirements specified in 26.9.2.1.

In some cases, it is possible to encounter emission requirements more stringent than the pre-existing ambient air quality. The Contractor assumes all exhaust emissions are net emissions, above those pre-existing in the ambient air background quality.

7.7 Water, steam and other emissions

The Purchaser shall specify the existing constraints on other emissions (which are specified in regional, national or local regulations) on the information data sheet. Such emissions may include, but are not limited to, the following:

— water discharge to streams, rivers or lakes;

— water discharge to foul water or sewage systems;

— emissions of hot saturated air or steam;

— lube oil vapour emissions;

— gas fuel venting;

— thermal emissions.

7.8 Visible plumes

● If requested by the Purchaser, a specific requirement relating to the visibility of exhaust stack and oil demister vent plumes during normal operation shall be provided on the document data sheet. The Contractor shall state on the document data sheet whether they can predict by analysis and/or measure site plumes. Where the risk of plumes endangers a road or railway in the proximity of the equipment, the Contractor shall deliver information about that plume formation to allow the Purchaser to evaluate the risk.

8 Contract fuels

8.1 General

The Purchaser shall provide detailed fuel properties, including composition, lower heating value and density derived in accordance with ISO 6976, and all known contaminant levels, limits of variability and the supply pressure and temperature to the Contractor for gas or liquid fuel(s) as selected in the information data sheet (see 4.1). Besides design condition fuel, the minimum and maximum values shall be made available. Refer to ISO 3977-4:2002, 5.2 for further information. It is the Purchaser's responsibility to ensure that the contract fuels supplied meet the fuel specifications.

8.2 Types (gas, liquids and combination)

Gas turbines may operate with gas, liquid or a combination of both primary fuels or mixed co-firing with liquid and gas fuels.

The gas turbine package shall be capable of running on either a single gas or single liquid fuel or as dual fuel with operation on either gas or liquid fuel and changeover between fuels at load as applicable with the Purchaser's requirements. The maximum load at which fuel changeover may take place shall be documented on the information data sheet.

● If requested by the Purchaser, the gas turbine package shall be capable of running on both gas or liquid fuels with on load fuel changeover (in both directions).

● If requested by the Purchaser, the Contractor shall advise on the capability to provide mixed co-fired fuel operation (and specifically the range of percentage of each fuel specified by the Purchaser), the specific maintenance penalties and any operating restrictions or additional maintenance inspections for the range of fuel mix combinations. Details shall be provided in accordance with the document data sheet.

8.3 Fuel composition

The Contractor shall define the fuel types and ranges of fuel qualities acceptable for the gas turbine application and use ISO 4261 or equivalent regional or national standards as applicable for both fuel gas and liquid fuel oil. Details shall be provided in accordance with the document data sheet. For general guidance on fuel chemical and physical properties refer to ISO 3977-4:2002, 5.4 for gaseous fuel and ISO 3977-4:2002, 5.5 for liquid fuel. Where specific fuel limitations exist relative to specific gas turbine models, such as the Wobbe index, these shall be explicitly stated. In the case of the Wobbe index, the calculation method used by the Contractor shall be stated. Measured values for composition or specific properties shall quote the associated preferred test or calculation standard. These may include liquid and gaseous fuels; fuel emulsions may also be considered.

The Contractor's fuel specification shall ensure the reliability, availability, maintainability and durability of the turbine and associated systems. The specifications shall address the fuel qualities needed to support reliable combustion including supply temperature and margins, table of allowable contamination levels and allowable carryover from upstream equipment and additional factors, where applicable. Examples of additional factors include the allowable content of hydrogen, sulfur, hydrogen sulfide and the viscosity and heating values, which may lead to degradation of the combustion process, turbine hot-section, and fuel control system, as well as compromise the safety of the turbine operation.

For the project fuel(s) the Contractor shall ensure that requirements are correctly identified and suitable measures taken for the proper operation of its scope-of-supply equipment.

The Purchaser shall provide the maximum dew point temperature for the contract gaseous fuel on the information data sheet. The Contractor shall check the dew point value against the constituents and provide a margin to this temperature on the information data sheet.

● If requested by the Purchaser, where a fuel composition that meets the Contractor's fuel requirements is unavailable, the Contractor shall define in accordance with the document data sheet, where possible, details of technical measures to upgrade the combustor, hot gas path components or fuel supply system (see Clause 9) to cope with the out-of-specification fuel and advise on the possibility for fuel treatments (such as washing or dosing) to reduce the impact of fuel contamination.

The Contractor shall advise, based upon the information provided by the Purchaser, details of the economic impact of out-of-specification fuels in terms of reduced maintenance intervals in accordance with the document data sheet. The Contractor shall identify the components at risk, the possible degradation mechanism (such as hot corrosion) that may apply and the impact on component life.

8.4 Fuel supply requirements

The Contractor shall document the fuel supply requirements in accordance with the document data sheet. Fuel supply condition requirements shall include the minimum and maximum pressure, the limits for temperature and the minimum flow rate(s) stated at the Contractor's terminal point.

Also quoted shall be the maximum allowable rate of change of supply conditions to meet all operating conditions.

● If requested by the Purchaser, where the Contractor's fuel supply requirements cannot be met, the Contractor shall document in accordance with the document data sheet, where possible, technical measures to meet the delivery conditions (see Clause 9).

8.5 Alternative fuels (syngas, low calorific value gas, LPG, NGL, Naphtha, LNG, high hydrogen and residual fuel oil)

● If requested by the Purchaser that operation on a non-standard fuel is required, including, but not limited to, syngas, low calorific value gas, liquid petroleum gas (LPG), natural gas liquids (NGL), naphtha, liquefied natural gas (LNG), high hydrogen and residual fuel oil, the Purchaser shall provide composition and supply condition details for the fuel document in accordance with the document data sheet. The Contractor shall document the fleet experience with the applicable fuel and the expected impact on maintenance intervals, performance, component integrity and any modifications required to the gas turbine core or the fuel system including any potential corrosion, flame temperature and toxicity conditions that require special attention in accordance with the document data sheet.

● If requested by the Purchaser, the Contractor shall provide resources to carry out a specific hazard and operability (HAZOP) study for a non-standard fuel that may entail special precautions due to low ignition temperature or toxicity.

Where the auto ignition temperature of the fuel is such that uncontrolled ignition may occur due to hot internal temperatures of the gas turbine core, leading to dangerous overpressure conditions or uncontained component failure, an alternative start-up fuel shall be used which mitigates these risks. The applicable fuel system details shall be documented by the Contractor in accordance with the document data sheet.

Where low energy fuels are to be used, the Contractor shall propose and document a start-up fuel system, if required. Low energy value fuel gases have many specific complications associated with their properties and composition. The Contractor shall advise the Purchaser on the necessity for a start-up fuel if fuel vaporization or other problems are predicted. Details shall be provided in accordance with the document data sheet.

The Contractor shall document any limits for high levels of inert gases to avoid problems with low flame temperatures such as blow out and emissions in accordance with the document data sheet.

Low energy gases require a very high volume flow rate to achieve adequate output power. This may require a modified fuel supply system, fuel manifolds and even changes to the fuel burners. The Contractor shall advise the full scope of any modifications to the standard gas turbine, fuel system and auxiliary systems to operate with the specified low energy fuels. Specifically, the fuel compression systems and their configuration and works power demands required shall be identified early in the procurement phase as these requirements may be significant. Low energy fuel gases may have specific contaminants that may or may not be listed in the Contractor's standard fuel specification. Any limits specific to these gases shall be identified early in the procurement phase to allow the Purchaser to assess the economic impact of any maintenance constraints such as from hot corrosion of gas path components, ash formation or even sulfide/sulfate corrosion of carbon steel burners. Details of any modifications required and fuel limitations shall be documented in accordance with the document data sheet.

Fuels which have high hydrogen content are generally suitable from a combustion standpoint, if the fast reaction rate and high flame temperatures are provided for. Also, hydrogen's low volumetric heating value results in higher flow volumes compared to natural gas. The safe handling of high-hydrogen fuels is important as their low molecular weight allows them to rapidly diffuse in air and pass through gasket materials and joints that are generally impervious to natural gas. Hydrogen is a highly flammable gas with much wider limits of flammability than natural gas. It can also be absorbed into metals and cause a general loss of ductility or hydrogen embrittlement that can readily occur at ambient temperatures. In addition, high-hydrogen fuels may affect emissions and increase component maintenance intervals. Special gas detectors are typically required to sense hydrogen.

Other fuels such as naphtha have low lubricity and may impact the life of a fuel supply system by affecting pumps and fuel flow distribution equipment (flow dividers).

9 Fuel systems and treatment

9.1 General requirements

The gas turbine package fuel system shall comply with the requirements for equipment and safety defined in ISO 21789:2009.

9.2 Gas fuel supply

● If requested by the Purchaser, a pressure regulator shall be supplied for the gas fuel supply system set to regulate the gas fuel supply to the gas turbine package fuel system maximum allowed pressure. This may be located on the gas turbine package or in the fuel supply line.

● If requested by the Purchaser, a gas compression skid shall be supplied with a gas compressor and associated accessories and controls to boost the gas fuel supply pressure to the gas turbine package fuel system to the minimum pressure required. This skid will typically be located in the fuel supply line. Where an oil injected screw compressor is utilized, a demister oil eliminator shall be supplied that is designed to achieve the flow conditions while removing oil droplets, mists and vapour from the gas fuel supply to the level that complies with the Contractor's fuel specification. Details including type of compressor configuration, flow rate, discharge pressure and power consumption shall be documented in accordance with the document data sheet.

9.3 Liquid fuel supply

Where the head from the liquid fuel storage or pipeline supply does not supply the fuel at the minimum pressure required for the gas turbine package fuel system, a suitably sized liquid fuel pump (skid) shall be required. The location available for the pump shall be advised by the Purchaser.

● If requested by the Purchaser, a pressure regulator shall be supplied for the liquid fuel supply system set to regulate the liquid fuel supply pressure to the gas turbine package fuel system maximum allowed pressure. This may be located on the gas turbine package or in the fuel supply line.

● If requested by the Purchaser, a liquid fuel forwarding skid shall be supplied with a low pressure liquid fuel pump and associated accessories to provide the liquid fuel at the minimum supply pressure to the gas turbine package fuel system. This skid may be located on the gas turbine package or in the fuel supply line.

9.4 Fuel filter/separator

9.4.1 Gas fuel

Service experience has found that liquid entrainment in fuel gas may occur despite installed fuel separation equipment. Entrained liquids would typically be hydrocarbon drop-out, which is a potential source of combustion problems in the gas turbine.

● If requested by the Purchaser, a combined gas fuel filter/liquid separator shall be supplied by the Contractor to eliminate the risk from off-specification fuels. The filter/liquid separator should be installed as close to or on the gas turbine package, to eliminate the risk of liquid drop-out from the gas fuel supply.

9.4.2 Liquid fuel

● If requested by the Purchaser, a liquid fuel filter shall be supplied by the Contractor, installed as close to or on the gas turbine package, to eliminate the risk from off-specification fuels of unacceptable solid particles in the liquid fuel supply.

9.5 Pre-heating requirements for the dew point control of fuel gas

The Purchaser shall ensure that, where applicable, measures shall be taken to ensure the temperature of the gas is kept above its dew point by implementing appropriate heating in the fuel gas supply according to the Contractor's fuel requirements. This facility may be placed at the entrance of the fuel pipeline to the site. The facility shall include isolation, separation, dew point heating and filtration in sequence of flow. It may also include metering and pressure control. The separator shall always be placed ahead of the dew point control. The temperature shall be maintained at an acceptable margin above its dew point downstream of the control by suitable heating of equipment and piping within the supply to and on the gas turbine package. The margin above dew point, where applicable, shall be specified on the information data sheet.

Where required, the Contractor shall provide trace heating to maintain the temperature of the gas fuel on the gas turbine package.

9.6 Pre-heating requirements for liquid fuels approaching their pour point

The Contractor shall identify all the heating requirements prior to pumping and the recommended heating source for fuels that might approach their pour point while not in operation and during operation in accordance with the document data sheet. Where failure of the heating source would result in solidification or difficult to remove fuel residues, measures, e.g. redundant heating systems, shall be proposed by the Contractor. The margin above pour point, where applicable, shall be specified on the information data sheet.

Piping and associated equipment shall be trace heated to maintain the supply temperature and prevent formation of contaminants leading to blockage. Winter grade fuel shall be used where possible to minimize the potential for pour point problems.

9.7 Alternative fuels – multi-fuel capability

Where the Purchaser requires the gas turbine to run with more than two primary fuels (see 8.2) the Contractor shall identify the specific modifications to equipment and the control systems to ensure stable and reliable operation of the gas turbine combustion system during alternative fuel running in accordance with the document data sheet. All safety, operational and maintenance considerations shall be identified and necessary modifications implemented. Specifically, any unique hazards associated with alternative fuels shall be identified and assessed using the guidance provided in ISO 21789:2009.

9.8 Mixed fuel co-firing

Where the Purchaser requires the gas turbine to run with mixed fuel co-firing operation (see 8.2), the Contractor shall advise if a mixed co-firing fuel operation can be achieved with the fuels stated by the Purchaser. The Contractor shall provide the permissible flow splits utilizing these fuels and shall identify the specific modifications to equipment and control systems required to ensure stable and reliable operation of the gas turbine combustion system during the mixed co-firing operation. Details shall be specified in accordance with the document data sheet.

All safety, operational and maintenance considerations shall be identified and necessary modifications implemented. Specifically, any unique hazards associated with co-firing shall be identified and assessed using the guidance provided in ISO 21789:2009.

9.9 Fuel for igniter

For some gas turbines an alternative fuel is required in support of the igniter.

Where applicable, the Contractor shall identify and document the igniter fuel type, pressure and flow (e.g. natural gas or propane) and the storage capacity required in accordance with the document data sheet.

9.10 Start-up fuel, main fuel and fuel changeover

When the turbine's main or primary fuel is natural gas or liquid fuel, the turbine shall start, run and shutdown on these fuels without the need for changeover. For some gas turbines an alternative fuel for start-up, ignition only, run-up to full speed at no load or a specific part load, fuel changeover or for unloading and shutdown may be required.

Where applicable, the Contractor shall document in accordance with the document data sheet the alternative fuel type, pressure and flow (e.g. natural gas, propane or liquid fuel), operational requirements and the storage capacity required.

9.11 Water and steam injection systems

Where water or steam injection is required for NO_X emissions control or power augmentation, the Contractor shall advise the Purchaser in accordance with the document data sheet and shall provide the water or steam delivery and control system as part of the gas turbine package. The maintenance plans, including outage schedules and component lives, as required in 28.4, specific to a water or steam injected gas turbine core shall be supplied by the Contractor. (See Clause 6 for water and steam details.)

9.12 Fuel purge, vents and drains

Gas turbines utilizing liquid fuels, either as the sole fuel or as part of a multiple-fuel application, typically require purge systems to remove residual liquid fuel from the injectors following a fuel transfer or gas turbine shutdown or to prevent fuel and combustor gases from entering inactive fuel or air passages. Typical fluids used as purge media include air, nitrogen, water and gas fuel. Fuel purge systems shall be designed in accordance with ISO 21789:2009. The purge delivery and control system shall be part of the gas turbine package. Where an external purge media (such as nitrogen) system is required, the Contractor shall provide purge media requirements including purge media type, quality and consumption rate for a start-up and shut down cycle in accordance with the document data sheet (see Clause 6).

Vents and drains shall comply with the requirements of ISO 21789:2009.

9.13 Fuel system metering

● If requested by the Purchaser, a fuel flow meter shall be supplied in the main and back-up (where installed) fuel system(s) to monitor the total volumetric fuel flow to the gas turbine. Turbine meter and orifice plate flow measurement devices shall comply with ISO 9951 and ISO 5167-1 respectively. The

Contractor shall install a flow computer to allow volumetric flow (from the main and back-up fuel) to be calculated from the meter(s) raw data and supplied to the control system. The Contractor shall advise, on the information data sheet, the type of flow meter(s) employed, the applicable standard(s) for the meter(s) and which fuel gas flow units are employed.

● If requested by the Purchaser, on-line component analysis of the fuel gas by chromatography shall be installed on the fuel supply at a suitable location. The chromatograph shall supply this data to either a dedicated flow computer or the gas turbine control system to calculate compressibility, density and fuel mass flow. The system shall also provide lower calorific value. The Contractor shall supply the details of the systems, the standards applicable to calculation of compressibility, density and calorific value and the outputs available to the gas turbine control system in accordance with the document data sheet.

9.14 Fuel system pipework and vessels design

9.14.1 General

Fuel gas and liquid pipework shall be implemented in accordance with 30.6 and 30.7.

9.14.2 Fuel pipes, joints and flanges

Fuel gas and liquid pipework downstream of the fuel filter(s) shall be constructed from corrosion-resistant materials suitable for the application.

Fuel gas pipe spools shall be constructed from welded pipe components jointed by full penetration welds. Components using slip-on style flanges do not require full penetration welds, however, all welds shall be manufactured and volumetric inspection carried out in accordance with the design and inspection codes.

9.14.3 Flexible pipes

The design, manufacture and test of corrugated flexible metal hoses and hose assemblies for use in the fuel delivery shall comply with ISO 10380. The design shall take into account operating pressures, temperatures, installation bend radius and the magnitude and direction of vibration. The Contractor shall provide a finite life for the flexible pipes based upon the design calculations on the information data sheet.

The installation of flexible fuel pipes shall avoid kinks, twisting and the possibility of abrasion from contact with other objects. The Contractor shall provide procedures for the removal and fitting of the flexible pipes during maintenance. Guidance shall be provided for the nature and frequency of inspections and testing to ensure pipe integrity during service operation.

Where specialized non-metallic flexible hoses are used on liquid fuel lines, the Contractor shall provide the Purchaser with the detailed hose specification for their approval in accordance with the document data sheet.

10 Regulations, codes and standards

10.1 General requirements

Where international, regional (e.g. EN), national and local regulations exist for the safe reliable operation of the power plant and the control of discharges, the equipment shall be designed to comply, control and monitor as applicable for compliance as specified by the Purchaser as well as complying with the content of Clause 14.

The Contractor shall comply with applicable regulations and legislation relating to the equipment supplied in the country where the equipment is installed. The Purchaser shall provide details of all the applicable regulations and legislation in accordance with the document data sheet.

This may include, but not be limited to, applicable regulations and legislation that apply to the following.

- Pressure equipment and systems covering pressure vessels, pressure equipment, pressure systems and transportable pressure vessels.
- Equipment in explosive atmospheres.
- Electrical equipment, covering disposal, electromagnetic compatibility, voltage, batteries.
- Equipment markings and identification.
- Emissions, including air contamination (arsenic, benzene, carbon monoxide cadmium, lead, mercury, nickel, nitrogen dioxide, ozone, polycyclic aromatic hydrocarbons, sulfur dioxide, nitrogen) and combustion exhaust outlets.
- Safety, covering machinery, construction products, personnel protection, materials.
- Pollution, covering noise, water intakes/discharges, batteries, soil, waste management.
- Fuel, covering contamination, content (sulfur, hydrogen sulfide).
- Firefighting equipment.
- Hazardous area classification.

The Contractor's obligations under these regulations include, but are not necessarily limited to, the roles of designing, manufacturing, construction and commissioning.

10.2 Design codes and standards

The Contractor shall provide equipment designed, manufactured/constructed and tested in accordance with internationally recognized design and engineering standards appropriate to the duty, operational requirements, safety requirements and environmental conditions that are applicable.

It shall be demonstrated that the design and construction complies with good engineering practice and that all equipment and materials are fit for purpose and compliant in all respects with the proposed duty.

The tender shall include a list of major standards, in accordance with the document data sheet, with which the Contractor proposes to comply.

Where regulations or directives given by authorities mention particular design or engineering standards as methods of compliance, the Contractor shall give preference to applying these standards in the design, manufacture and construction of the relevant parts of the power plant. If the Contractor proposes to employ an alternative standard, this shall be brought to the attention of the Purchaser for approval. When seeking such approval, it shall be the Contractor's responsibility to provide the appropriate documentation for comparison.

Consideration shall also be given to the implication of changes and amendments to applicable codes and standards issued before the contract is signed.

The Contractor shall be consistent in their application of the specified standards in this document. If an alternative international or national standard is normally used by the Contractor such use shall require approval by the Purchaser.

10.3 Verification

Before the contract is placed, there shall be agreement over the conformity assessment procedures to be used, and provision for the Purchaser to comment.

● If requested by the Purchaser that independent assessment of the design and/or construction processes or written schemes of examination are required for compliance with regulations and legislation, the Contractor shall document the proposed method/format of such verification schemes.

The Purchaser shall document any variations required or an alternative system required such that the Contractor may integrate these activities into their own systems for compliance. Documentation shall be in accordance with the document data sheet.

The Contractor shall supply information and documentation that is necessary to allow the Purchaser to fulfil their obligations with respect to the applicable regulations and directives.

Where written verification schemes of examination are prepared by the Contractor they shall

— be approved as required by applicable regulations,

— identify the scope of the initial examination performed by the Contractor as initial purchaser of the equipment and systems, and

— be delivered to the Purchaser in advance of commissioning of the equipment and systems to which they apply.

The Contractor shall be responsible for ensuring that the examination of the power plant is carried out, in accordance with the applicable regulations and directives, before the power plant is brought into service.

For any in-service examination of the power plant in accordance with the written verification schemes required by the applicable regulations or directives (subsequent to takeover), the appointment of an engineering inspection organization fulfilling the role of competent person shall be the responsibility of the Purchaser, unless otherwise defined by the Purchaser in accordance with the document data sheet.

11 Operating requirements

11.1 General requirements

The Purchaser shall specify at the tender stage in the information data sheet the total annual number of starts per fuel (hot, warm and cold: see 11.3 for definitions), and the total annual operating hours per fuel.

11.2 Operating range and limitations

The minimum output of a gas turbine package shall be taken to be a unit [with the steam turbine and the gas turbine(s) in service in case of combined cycle gas turbine (CCGT)] operating at a fraction of maximum output and meeting all environmental constraints as specified for a continuous operation. The output range between MCR and MEL shall be the nominal operating range of the gas turbine package and this shall be confirmed by the Contractor. The Contractor shall advise any operating restrictions for extended operation between MEL and MCR in accordance with the document data sheet.

A higher output or peak load as defined in 5.1.4 is a higher net output than maximum nominal output that may be selected and may be achieved by a higher TIT, water or steam injection or inlet cooling. The Contractor shall advise any operating restrictions for extended operation at peak load in accordance with the document data sheet. The Contractor shall define any operating and technical limitations that apply from operating for extended periods at MEL.

11.3 Starts (time to start, number of starts, start restrictions)

The start-up time is defined as the elapsed time between the instant when start-up is initiated and power is available to the grid connection at MCR for the gas turbine package. The start-up time may vary according to the technology involved.

The Contractor shall state the constraints on the number of repeated starts (in the event of failed starts) on the gas turbine and the reason for the constraint in accordance with the document data sheet. The Contractor shall further declare whether the constraint on repeated starts relates to a specific thermal state (hot or warm start) and provide the reason for the constraint. The waiting time before restart shall be quoted by the Contractor in cases where the maximum number of starts are reached.

The Contractor shall provide specific advice (including barring requirements) for repeated starts in the operating manual.

Start times shall be provided for hot, warm and cold starts in minutes. The following definitions are made to allow comparison between Contractors.

— Shutdown refers to the point at which the unit shutdown is initiated by the operator via the control system.

— A start-up refers to the point at which the unit start is initiated by the operator via the control system.

— A hot start shall be defined as < 4 h from the shutdown of the unit.

— A warm start shall be defined as between 4 h and 40 h after shutdown.

— A cold start shall be defined as > 40 h from the shutdown of the unit.

NOTE The start times above are typical but will vary depending on the size and structure of the gas turbine.

Where start times are modified based upon the thermal condition of the steam side (in a combined cycle) and where a stack damper is available (to reduce thermal siphoning losses through the stack) these shall be quoted instead of a standard combined cycle start time.

The Contractor shall provide the time (included in a start) for exhaust (and heat recovery steam generator, if installed) purge to comply with the requirements of ISO 21789:2009.

● If requested by the Purchaser, the Contractor shall provide a fast start option (with a higher loading ramp rate than normal) covering hot, warm or cold start conditions and the corresponding start times (in minutes). The Purchaser shall supply their preferred fast hot, warm and cold start times on the information data sheet.

11.4 Loading/de-loading

The loading and de-loading shall be automatic. Where applicable, the target load is entered manually by the operator. The Contractor shall provide details of loading and de-loading ramp rates and loading conditions for hot, warm and cold starts. The ramp rate for loading from synchronization to MCR and de-loading from MCR to de-synchronization shall be provided as MW/min or % of MCR/min on the document data sheet. Differences between gas turbine package loading rate and CCGT loading rate shall also be provided.

The Purchaser shall provide any required loading rate in the information data sheet.

The Contractor shall ensure that the gas turbine package is emission compliant when loading and de-loading between MEL and MCR.

During a fast load ramp there is the possibility that the demanded load and the corresponding exhaust gas emission is temporarily exceeded with the risk to the operator of having to report non-compliance to the regulatory authorities.

● If requested by the Purchaser, the Contractor shall state the expected load/emission overshoots during ramping in a document provided in accordance with the document data sheet.

The Contractor shall state any limitations from load cycling between MCR and MEL and between synchronization and MCR.

11.5 Grid operational requirements

The gas turbine package shall be capable of operation in accordance with the grid code or technical constraints of an electrical network or system where required. This shall include continued operation within the stated grid frequency range. The Purchaser shall identify and document the applicable grid code in accordance with the document data sheet. The Contractor shall document any restrictions to the grid code requirements caused by physical limitations in accordance with the document data sheet.

The gas turbine package shall be capable of being synchronized on a stabilized grid within a specified range around the nominal frequency.

11.6 Frequency response

● If requested by the Purchaser, the gas turbine package shall be capable of providing automatic changes in load to assist grid frequency changes in a proportional response as required by the grid code. This requirement is typically called frequency response. The frequency sensitive mode or limited frequency sensitive mode shall be capable of being selected and enabled manually. This feature shall be selected in the options data sheets by the Purchaser. The control system requirements for this capability are given in 26.1.7.

11.7 Location of controls HMI

● The location of the local controls human machine interfacing (HMI) for the power generation package shall be located as defined by the Purchaser either being located on or adjacent to the gas turbine package/power generation package, in an adjacent control room or a control room remote from the power generation package but within the power plant.

● If requested by the Purchaser, an offsite remote control function shall be provided. The level of control and method of access required shall be documented by the Purchaser in accordance with the document data sheet. The functions supplied and the reliability, integrity and security for communications between the remote and local control systems shall be considered and demonstrated by the Contractor to the Purchaser to achieve an equivalent safety integrity level as achieved for the local controls.

11.8 Operation documents

The Contractor shall provide an operating manual with the operating modes of the gas turbine package and any constraints this places on gas turbine operation. The manual shall describe all steady-state and transient operations such as starting, synchronisation, loading, de-loading, de-synchronisation and shutdown. It shall also describe any optional modes selected by the Purchaser such as peak firing, part load operation, frequency response and fast starts, and any foreseeable abnormal events and the recommended actions for the operator. Alarms and protections shall be described in the C&I documentation (see Clause 26).

An operating manual shall be supplied prior to the initial commissioning of the unit at site.

11.9 Island mode operation and black start

● If required by the Purchaser, the power generation package may be required to operate in Island mode. Therefore, the gas turbine package control system shall have to manage voltage regulation and frequency control. The Purchaser shall advise the nature of the network and identify who is responsible for network control in accordance with the document data sheet. It should be noted that small grids with several producers may require a special controls concept.

Black start is defined as the ability to start the gas turbine package without connection to the electricity grid. This typically requires power supplied by a dedicated auxiliary diesel package.

● If requested by the Purchaser that black start is a requirement, the auxiliary start package shall be supplied and sized to allow sufficient power for gas turbine auxiliary systems and for the gas turbine starting system. Where more than one gas turbine package is installed on site, there shall be sufficient interconnection for one unit to supply power for the other units to start. The black start capability shall be compliant with the local grid code and shall be capable of not less than three successive black starts (see 30.2.3).

11.10 Black start and black grid restoration

Black grid restoration is defined as the ability to energize part of the grid or, if appropriate, the host distribution system, followed by the capability to accept instantaneous loading of demand blocks of a defined size and controlling frequency and voltage levels within acceptable limits during the block loading process.

● If requested by the Purchaser that black grid restoration is required, the details of the grid restoration procedure, including size of required load steps, overall demanded load, applicable fuel, details of local transmission and distribution system, shall be provided by the Purchaser for development of a basic concept in accordance with the document data sheet.

12 Quality

12.1 Quality management system

12.1.1 General

The Contractor and its major subcontractors shall operate a quality management system (QMS), e.g. ISO 9001, or any corresponding regional or national standard that complies with its elements.

The scope of the QMS shall be directly relevant to the full projected scope of work to be undertaken, including both works and site activities. The QMS shall be available for review on the Purchaser's request.

Where the development, supply and maintenance of computer software is required as part of the project (or could affect the quality of the delivered product), the Contractor shall implement a QMS adapted to software (e.g. ISO/IEC 90003).

The project quality activities shall be defined clearly by the Contractor in a project quality plan (PQP). The PQP shall cover all stages of the project and be applicable to all major subcontracts. The PQP should follow the guidance given in ISO 10005.

12.1.2 Project quality manager

The Contractor shall appoint a qualified quality assurance manager who shall be responsible for the management and implementation of the quality assurance arrangements for the project and serve as the direct coordination interface with the Purchaser.

12.1.3 Project quality plan

At an early stage in the contract the Contractor shall submit a PQP in accordance with the document data sheet. The PQP shall define the programme of quality control and inspection activities that shall be implemented by the Contractor to ensure that the design, procurement, manufacture and completion of the materials and equipment comply with the specified requirements. The Purchaser shall document any variations required on the submitted plan in accordance with the document data sheet.

The PQP shall include the name of major manufacturers and major subcontractors. The PQP will be revised to include further details during the course of project execution.

The PQP shall cover all aspects, as far as applicable, according to the QMS.

The PQP shall define the following:

— project organization for all activities during all stages of the project;

— duties and responsibilities for the key roles within the project;

— organizational interfaces, internal and external;

— communication links between all parties in terms of scope, extent, periods and participants, including reporting and follow-up of action items.

12.1.4 Quality control plan

The Contractor shall prepare as required, in accordance with the document data sheet, and maintain quality control plans (QCP) that detail the controls that are to be used in managing quality throughout the project phases (design, procurement, manufacture, erection, commissioning, inspection, testing and take over) with respect to work undertaken directly by and subcontracted by the Contractor.

The QCP(s) shall typically include

— reference to controlling standards, specifications, drawings, instruction references, etc.,

— inspections and tests to be carried out (including frequency), and

— quality records and documents to be produced specific to the activity, which shall be used to ensure compliance with the contract requirements.

The QCP(s) shall be formatted to allow the Purchaser to identify those specific activities that are to be included within their own programme of verification. The QCP(s) shall be submitted to the Purchaser in advance of the activity to which they relate to enable the Purchaser to establish their surveillance intention. The QCP(s) shall be uniquely identified with a specific reference number, which shall be defined on each page of the document, along with the page numbers.

The Contractor shall mark-up each QCP, prior to submission to the Purchaser, to indicate specific inspection and verification stages and frequency of control checks carried out.

Upon completion of the package inspection, the signed QCP shall be part of the Final Quality Dossiers (Manufacturing Record Book).

12.1.5 Inspection and test plan

The Inspection and test plan (ITP) defined in accordance with the document data sheet shall detail all test and inspections that are performed during fabrication of the equipment in the workshop. The ITP shall identify the material and components with article numbers or project numbers in order to ensure that the issued test reports are traceable with the production order or article/project number.

The Contractor shall prepare, maintain and provide an ITP.

The Purchaser shall document the witness points required in accordance with the document data sheet. The Contractor shall document any variations required to the Purchaser’s requirements, including the reason for the variation.

The ITP shall also identify the acceptance criteria, procedures or standards for the test and inspections. Procedures written for local labour may be written in local language when referring to an international standard.

12.2 Quality monitoring and approval

12.2.1 Sub-suppliers and supply chain quality monitoring

The Contractor shall provide details, in accordance with the document data sheet, of major sub-suppliers and shall not replace any listed major sub-suppliers previously authorized in the contract without the prior written agreement of the Purchaser. The Contractor shall monitor their sub-suppliers in a programme of surveillance, inspection, reviews and audit.

12.2.2 Quality surveillance by the Purchaser

The Purchaser shall be permitted on request to review and monitor the Contractor's proposals and their execution of all aspects of the project. Within the respect of intellectual property rights (IPR) in agreement with the Contractor and upon the signature of a non-disclosure agreement, the Purchaser or the Purchaser's representative shall have access to all locations and, at reasonable times, where activities are performed as listed within the IPR.

A corrective action programme shall be defined by the Contractor to correct deficiencies revealed by the monitoring. The programme shall be approved by the Purchaser.

12.2.3 Equipment approvals of statutory and coded items

● If independent inspection is required, the Purchaser shall provide the Contractor with details of the inspecting authority or organization who they propose to appoint to survey the design, construction, inspection and verification of compliance to the stated standards and regulations in accordance with the document data sheet.

12.2.4 Quality control record

Following each visit to perform a quality control activity, the Purchaser or the Purchaser's nominated representative shall complete a quality control record (QCR).

The QCR shall

— identify the item inspected, the stage of manufacture, and the nature of the quality control carried out, and

— list all points that require remedial action by the Contractor, before the subject item can be released.

Once all actions from QCR have been closed, the Purchaser and Contractor shall co-sign the QCR to indicate that there are no more non-conformities pending identified by the Purchaser. The completed QCR shall be documented in accordance with the document data sheet.

12.2.5 Control of non-conforming products and services

The PQP shall include or reference the procedures concerning handling and control of all non-conformances and corrective measures, including those affecting subcontractors and contractors.

The Contractor shall keep records of all non-conforming items identified throughout the duration of the project. This shall reflect evidence of notification of the non-conformance to the relevant party and the suggested course of action or an instruction issued to rectify the situation where necessary. The Purchaser shall have the right to review these reports.

12.2.6 Concessions

The Contractor shall advise the Purchaser of any intention to seek a concession with respect to any permanent deviation from the terms and conditions of the project requirements in any of the following areas.

— Effects to terminal points where the mating item or system is outside of the Contractor's scope of supply.

— Deviations from the Purchaser's work specification.

— Deviations from the Contractor's submissions which have been accepted by the Purchaser.

— Deviations which reduce safety margins or allowances.

— Non-standard items which reduce the capability to interchange power plant items or components and/or increase the cost of replacements.

The Contractor shall maintain a record of concession types as defined above throughout the duration of the project. This shall reflect evidence of notification of the concession to the relevant party and the suggested course of action or an instruction issued to rectify the situation where necessary.

12.2.7 Project design reviews

A process of design reviews shall be implemented by the Contractor and the Purchaser to ensure that the specific provisions of the project are being met, in particular to ensure that design information relating to interfaces between different project areas is implemented in accordance with the project.

Project design reviews shall include such items as

— layout/interfaces,

— constructability,

— hazard area classification,

— environmental management,

— health and safety, and

— maintainability.

The design reviews shall be reported in accordance with the document data sheet.

13 Reliability, availability and maintainability

13.1 Basic RAM assessment

13.1.1 General

The following information covering reliability, starting reliability, availability and maintainability (RAM) shall be documented, in accordance with the document data sheet, by the Contractor in accordance with this clause based on the definitions and formula in ISO 3977-9:1999 for reliability and availability and supplemented by IEEE 762:2006 for maintainability. The scope of the assessment shall be the gas turbine package. The Purchaser shall provide targets for these requirements on the information data sheet.

For comparison purposes the measurements should be based on data representative of a specific operation, of a fleet period of at least 150 000 running hours and a fleet sample size of 3 units. The period shall include 2 basic maintenance and inspection periods and 1 major maintenance and inspection period for each unit. Where these values are not available the values used shall be defined with the RAM assessment data.

13.1.2 Reliability

Reliability is the probability of an item operating for a given amount of time without failure when used under specified conditions. More generally, reliability is the capability of parts, components, equipment, products and systems to perform their required functions for desired periods of time without failure, in specified environments and with a desired confidence.

Mean time between failures for the gas turbine package, based on ISO 3977-9:1999, 3.67, shall be used as a nominal measure of reliability, as shown in Formula (1):

$$\bar{t}_{MTBF} = \frac{t_{PH} - \left(t_{RSH} - t_{FOH} - t_{POH}\right)}{n_{FO}} = \frac{t_{SH}}{n_{FO}} \tag{1}$$

where

$\bar{t}_{MTBF}$ is the mean time between failures (MTBF);

t_{PH} is the period hours (PH);

t_{POH} is the planned outage hours (POH);

t_{RSH} is the reserve shutdown/service hours (RSH) (also known as planned maintenance shutdown hours);

t_{SH} is the service hours (SH);

t_{FOH} is the forced outage hours (FOH): time, in hours, during which the unit or a major item of equipment was unavailable due to forced (unplanned) outages;

n_{FO} is the number of forced outages (FO): unplanned component failure (immediate, delayed, postponed) or another condition that requires the unit to be removed from service immediately or before the next planned shutdown.

NOTE In ISO 3977-9:1999, 3.67, Formula (1) is written as $\mathrm{MTBF} = \frac{\mathrm{PH} - \left(\mathrm{RSH} - \mathrm{FOH} - \mathrm{POH}\right)}{\mathrm{FO}} = \frac{\mathrm{SH}}{\mathrm{FO}}$.

13.1.3 Starting reliability

Starting reliability is defined as shown in Formula (2):

$$F_{SR} = \frac{n_{SS}}{\left(n_{SS} + n_{FS}\right)} = \frac{n_{SS}}{n_{SA}} \tag{2}$$

where

F_{SR} is the start reliability (SR);

n_{SS} is the number of successful starts (SS);

n_{FS} is the number of failures to start (FS);

n_{SA} is the number of starting attempts (SA).

NOTE In ISO 3977-9:1999, 3.104, Formula (2) is written as $\mathrm{SR} = \frac{\mathrm{SS}}{\mathrm{SS+FS}} = \frac{\mathrm{SS}}{\mathrm{SA}}$.

Unless otherwise specified by the Contractor, failure to start is defined as a start attempt where the control system or operator aborts the starting procedure before the power generation package is synchronized to the grid. Reasons for aborting the start attempt are to be directly attributable to anomalous operation of the gas turbine and associated auxiliary equipment within the Contractor's scope of supply.

Failed starts attributable to the following causes should be excluded from the starting reliability calculation for the gas turbine.

— Systems and equipment not within the gas turbine Contractor's scope of supply.

— Events outside the Contractor's control: failure to use fuel in accordance with the Contractor's fuel specification, misapplication of equipment, owner or operator error, improper use by owner or operator.

— Need for owner's maintenance personnel to perform required responsibilities.

— Action or inaction of owner or operator adverse to the Contractor's operating manuals and specifications.

— Failures or abnormalities arising from parts and/or services provided or performed by parties other than the Contractor.

— Start failure due to post maintenance commissioning activities.

— Repetitive events where the operator re-initiated the starting sequence without identifying the root cause of the initial aborted start.

13.1.4 Availability

Availability is the probability that an item will be able to function (i.e. not failed, undergoing repair or undergoing planned maintenance/inspections) when called upon to do so. Availability measures are concerned with the fraction of time in which a unit is capable of providing service and accounts for outage frequency and duration.

Availability factor for the gas turbine package, based on ISO 3977-9:1999, 3.7, shall be used as a nominal measure of availability and is the fraction of a given reference period in which a generating unit is available without any outages, as shown in Formula (3):

$$F_{\mathrm{AF}} = 1 - \frac{t_{\mathrm{FOH}} + t_{\mathrm{POH}}}{t_{\mathrm{PH}}} = \frac{t_{\mathrm{AH}}}{t_{\mathrm{PH}}} \qquad (3)$$

where

F_{AF} is the availability factor (AF);

t_{FOH} is the forced outage hours (FOH);

t_{POH} is the planned outage hours (POH);

t_{PH} is the period hours (PH);

t_{AH} is the available hours (AH).

NOTE In ISO 3977-9:1999, 3.67, Formula (3) is written as $\mathrm{AF} = 1 - \frac{\mathrm{FOH} + \mathrm{POH}}{\mathrm{PH}} = \frac{\mathrm{AH}}{\mathrm{PH}}$.

13.1.5 Maintainability

Maintainability is the probability that an item will be retained in or restored to a specified condition within a given period of time when the planned maintenance is performed in accordance with the Contractor's prescribed procedures and resources. The term is also used to denote the discipline of studying and improving the maintainability of products, primarily by reducing the amount of time required to diagnose and repair failures.

For the purposes of this International Standard, the planned outage factor shall be used as a basic measure of maintainability, based on IEEE 762:2006, 8.1, as shown in Formula (4):

$$F_{\text{POF}} = \frac{t_{\text{POH}}}{t_{\text{PH}}} \tag{4}$$

where

F_{POF} is the planned outage factor (POF);

t_{POH} is the planned outage hours (POH);

t_{PH} is the period hours (PH).

NOTE In IEEE 762:2006, 8.1, Formula (4) is written as $POF = \frac{POH}{PH}$.

Values shall be supplied for

— basic maintenance and inspection: 8 760 hrs (1 year), and

— major service and inspection: 26 280 hrs (3 years) or less (using cumulated period hours).

Average forced outage duration (sometimes called mean down time) for the gas turbine package, based on IEEE 762:2006, 6.10.1, shall be defined as shown in Formula (5):

$$\bar{t}_{\text{FOD}} = \frac{t_{\text{FOH}}}{n_{\text{FO}}} \tag{5}$$

where

$\bar{t}_{\text{FOD}}$ is the average forced outage duration (FOD);

t_{FOH} is the forced outage hours (FOH);

n_{FO} is the number of forced outages (FO).

NOTE In IEEE 762:2006, 6.10.1, Formula (5) is written as $r = \frac{FOH}{Number\ of\ forced\ outages}$ where r is the average forced outage duration.

13.1.6 Spares holding

The Contractor shall advise the spares holding requirement required to achieve the applicable RAM requirements in accordance with 28.7 and ISO 3977-9:1999, 4.3 in accordance with the document data sheet.

13.1.7 Operating logs

The Contractor shall provide operating log requirements in accordance with ISO 3977-9:1999, Clause 5 covering the parameters used to validate applicable RAM requirements which shall be completed by the Purchaser throughout the life history of the equipment supplied in accordance with the document data sheet.

13.2 Additional RAM requirements

13.2.1 General requirements

Clauses 13.2.2 to 13.2.4 describe the additional options that may be specified by the Purchaser. RAM values are the Contractor's specific knowledge and cannot be provided without a confidentiality agreement (IPR) with the Purchaser.

● If requested by the Purchaser, the Contractor shall provide additional RAM assessment for forced outage factor (FOF) and equivalent forced outage factor (EFOF) identified in 13.2.2 and equivalent availability factor (EAF) identified in 13.2.3 for the gas turbine package. The assessment shall include RAM statistics, sample size, operational experience and assessment assumptions. Sample size shall be defined in terms of unit years of experience. Operational experience shall include the number of fired hours and fired starts on the population that is being used in the analysis. A RAM report shall be provided in accordance with the document data sheet including the following support elements and equivalent operating hours where selected in accordance with 13.2.4.

● If requested by the Purchaser, the basic RAM assessment should also be supported by the following elements:

— RAM Life Cycle Cost (LCC) Modelling;

— RAM Risk Assessment (assessment of potential deviations from the RAM model due to maintenance errors or development uncertainties);

— Risk Based Maintenance Rationalization Assessment [risk control matrix (RCM), maintenance steering group 3 (MSG-3), Risk Based Lifing]; further defined in MSG-3 Section 28 failure mode effect and criticality analysis (FMECA)/Fault Tree Assessments.

● If requested by the Purchaser for aero-derivative parts of the gas turbine core only, the additional RAM requirements shall be supported by the following elements:

— RAM LCC modelling;

— RAM Risk Assessment (assessment of potential deviations from RAM model due to maintenance errors or development uncertainties);

— Risk Based Maintenance Rationalization Assessment (RCM, MSG-3, Risk Based Lifing); further defined in MSG-3 Section 28 FMECA/Fault Tree Assessments.

13.2.2 Forced outage factor and equivalent forced outage factor

Forced outage factor is the fraction of a given operating period in which a generating unit is not available due to forced outages. Equivalent forced outage factor is the fraction of a given operating period in which a generating unit is not available due to forced outages and deratings. It accounts for Class 0, Class 1, Class 2 and Class 3 unplanned outage states as defined by IEEE 762:2006, 4.1.2.2. See Formulae (6), (7) and (8):

$$F_{\mathrm{FOF}} = \left(\frac{t_{\mathrm{FOH}}}{t_{\mathrm{PH}}} \right) \times 100 \tag{6}$$

$$F_{\mathrm{EFOF}} = \left(\frac{t_{\mathrm{FOH}} + t_{\mathrm{EFDH}}}{t_{\mathrm{PH}}} \right) \times 100 \tag{7}$$

$$F_{\mathrm{EFOF}} = \left(\frac{\sum_{i=1}^{n} n_{\mathrm{FD}i} \times t_i}{C_{\max}} \right) \tag{8}$$

where

F_{FOF} is the forced outage factor (FOF);

F_{EFOF} is the equivalent forced outage factor (EFOF);

t_{PH} is the period hours (PH);

t_{FOH} is the forced outage hours (FOH);

t_{EFDH} is the equivalent forced derated hours (EFDH);

$t_{\mathrm{E(x)}}$ is the equivalent hours in the time category, x, represented by parentheses;

$n_{\mathrm{FD}i}$ is the number of forced derated states (FD_i);

t_i is the time in hours accumulated in the time category of interest between the *i* th and the (*i* + 1) th change in either available capacity (unit deratings) or dependable capacity (seasonal deratings);

$C_{\max}$ is the maximum capacity (MC).

NOTE 1 In IEEE 762:2006, 8.3, Formula (6) is written as $FOF = \left(\frac{FOH}{PH} \right) \times 100$.

NOTE 2 In IEEE 762:2006, 8.20, Formula (7) is written as $\left(\frac{FOH + EFDH}{PH} \right) \times 100$.

13.2.3 Equivalent availability factor

Equivalent availability factor is the percentage of a given operating period in which a generating unit is available without any outages and equipment or seasonal deratings. Equivalent availability factor for the gas turbine package shall be based on ISO 3977-9:1999, 3.23, as shown in Formula (9):

$$F_{\mathrm{EAF}} = \frac{t_{\mathrm{PH}} - \left(t_{\mathrm{EUDH}} + t_{\mathrm{EPDH}} + t_{\mathrm{ESEDH}} \right)}{t_{\mathrm{PH}}} \times 100 \tag{9}$$

where

F_{EAF} is the equivalent availability factor (EAF);

t_{PH} is the period hours (PH);

t_{EUDH} is the equivalent unplanned derated hours (EUDH): product of the unplanned derated hours (UDH) and the size of reduction, divided by the net maximum capacity (NMC) summated over planned derated hours;

t_{EPDH} is the equivalent planned derated hours (EPDH) and represents the available hours during which a basic or extended planned derating was in effect = product of the planned derated hours (PDH) and the size of reduction, divided by the net maximum capacity (NMC) summated over planned derated hours;

t_{ESEDH} is the equivalent seasonal derated hours (ESEDH) and represents the available hours during which a seasonal derating was in effect = net maximum capacity (NMC) minus the net dependable capacity derated hours (NDC), multiplied by the available hours (AH) and divided by the net maximum capacity (NMC) summated over planned derated hours.

NOTE In ISO 3977-9:1999, 3.23, Formula (9) is written as $\mathrm{EAF} = \frac{\mathrm{PH} - \left(\mathrm{EUDH} + \mathrm{EPDH} + \mathrm{ESEDH}\right)}{\mathrm{PH}} \times 100\%$.

Note that EUDH, EPDH or ESEDH may be calculated as in Formulae (10) (11) and (12), respectively:

$$t_{\mathrm{EUDH}} = \frac{\sum_{i=1}^{n} n_{\mathrm{UD}i} \times t_i}{C_{\max}} \tag{10}$$

$$t_{\mathrm{EPDH}} = \frac{\sum_{i=1}^{n} n_{\mathrm{PD}i} \times t_i}{C_{\max}} \tag{11}$$

$$t_{\mathrm{ESEDH}} = \frac{\sum_{i=1}^{n} n_{\mathrm{SD}i} \times t_i}{C_{\max}} \tag{12}$$

where

n_{UDi} is the number of unplanned derated states (UD_i);

n_{PDi} is the number of planned derated states (PD_i);

n_{SDi} is the number of seasonal derated states (SD_i);

t_i is the time in hours accumulated in the time category of interest between the *i* th and the (*i* + 1) th change in either available capacity (unit deratings) or dependable capacity (seasonal deratings);

C_{max} is the maximum capacity (MC).

NOTE Seasonal derated hours are not included in planned derated hours, but they are included in calculating the EAF.

13.2.4 Equivalent operating hours

● If requested by the Purchaser, the Contractor shall provide the equivalent operating hours (EOH) in accordance with ISO 3977-9:1999, 4.1.2.1 for the gas turbine package or the Contractor's equivalent definition in accordance with the document data sheet.

14 Safety requirements

14.1 General

The gas turbine package shall comply with the safety requirements of ISO 21789:2009.

The Contractor shall ensure that all the safety instructions relating to installation, commissioning, testing, operation and maintenance are included in the relevant manuals.

Hazards generated by included equipment which are additional to the scope of ISO 21789:2009 shall be assessed in accordance with the principles of ISO 12100 and appropriate measures taken until adequate risk reduction has been obtained in accordance with ISO 21789:2009. Examples of such requirements would include, but not be limited to, materials, hazardous materials, guarding, warning signs, warning notifications in operating instructions, isolation and permit to work. Risks external to the interface boundaries of this International Standard as defined in the Scope (Clause 1) are not covered.

Unit orientation to support gas turbine package safety and maintainability requirements in accordance with ISO 21789:2009, 5.10.5.5 and 5.10.6.5 shall be considered.

14.2 Risk assessment

In addition to the risk assessment requirements of ISO 21789:2009, risk assessments shall be performed covering both operational and maintenance activities to determine whether the equipment or collateral damage outside the scope of ISO 21789:2009 can cause injury to people or pose a threat to people's lives, or to the environment. The results of the assessments shall be documented in accordance with the document data sheet. Where risk reduction measures are undertaken, it is essential to ensure that potential hazards introduced by the additional measures are evaluated through risk assessment. Risks identified during risk assessment shall be reduced until adequate risk reduction is achieved. The level of risk obtained assumes that the operation and maintenance procedures defined by the Contractor ensure that the obtained levels of risk are maintained throughout the life of the equipment.

Any residual risks identified by the Contractor shall be documented, in accordance with the document data sheet, and communicated to the Purchaser who shall take additional mitigation action as necessary and where applicable. If new information indicates there is an additional increased risk before adequate risk reduction has been achieved, operators of affected equipment shall be advised. Additional mitigation actions taken by the Purchaser shall be communicated to and approved by the Contractor.

14.3 Fire precautions

14.3.1 General

The fire precaution concepts detailed in ISO 21789:2009, 5.15 shall be applied to the total scope of equipment within this International Standard. The fire protection system shall be based on an integrated set of standards and the guidance described in ISO 21789:2009, 5.15.2 to 5.15.13 inclusive and any applicable regulations and legislation identified by the Purchaser in accordance with Clause 10.

A cause and effect diagram and associated documentation shall be provided for fire protection systems (see 35.4).

Where regional, national or local regulations dictate special requirements for fire systems, any such regulations shall be specified by the Purchaser and documentation of the regulations made available to the Contractor and documented in accordance with the document data sheet (see Clause 10).

14.3.2 Enclosure fire precautions

The fire precaution concepts detailed in ISO 21789:2009, 5.13.3 shall be applied to all enclosures within the scope of this International Standard.

14.3.3 Gas turbine hall fire precautions

The fire precaution concepts detailed in ISO 21789:2009, 5.26 shall be applied to unenclosed gas turbines or any other similar equipment posing a fire risk installed in a gas turbine hall.

14.4 Hazardous area classification and explosion prevention and protection

Where the potential exists for flammable gases, vapours or mists to arise, the areas covered by the scope of ISO 21789:2009 and additional equipment within the scope of this International Standard shall be classified jointly by the Purchaser and Contractor and appropriate precautions shall be taken against explosions in accordance with the requirements specified in ISO 21789:2009, 5.16 and where applicable the ventilation requirements specified in ISO 21789:2009, 5.17.

Where hot surfaces exist or can exist in the hazardous zone the requirements of ISO 21789:2009, 5.17.5 shall apply.

Solid and flexible conduits shall be provided with a sealing device where entering or leaving a hazardous area to maintain the appropriate degree of protection in accordance with IEC 60079-14:2013, 9.4.

The Contractor shall supply a hazardous area drawing or definition covering the equipment within the Contractor's scope of supply and shall include hazardous zone definitions, fuel types, allowed temperature class and expected ambient temperature range in accordance with the document data sheet.

14.5 Flammable gas detection

Where the potential for an explosive atmosphere exists due to a leak from equipment of a flammable gas or vapour, enclosures and/or gas turbine halls shall be fitted with a gas detection system in accordance with ISO 21789:2009, 5.19. Where applicable, the need to locate detectors in the vicinity of potential leak sources shall take account of the credible leak sizes, the effect of ventilation and the different conditions between the starting and running of equipment.

14.6 Heat detectors

Heat detectors shall form part of a fire detection system as specified in ISO 21789:2009, 5.15.5.

14.7 Smoke detection

● If requested by the Purchaser, a smoke detection system shall be installed for control room computer/instrumentation equipment and shall be tested by the Contractor before the computer/instrumentation system is left powered up and unattended. Details supplied shall be defined in accordance with the document data sheet.

14.8 Enclosed space access

Access to enclosures shall comply with the requirements of ISO 21789:2009, 5.13 and the recommendations in ISO 21789:2009, 7.6. Access to enclosures and enclosed spaces shall comply with the general requirements contained in ISO 21789:2009 (see 29.2.7 and 29.2.9 for further requirements).

14.9 Containment and rupture

All rotating parts that are relevant for safety shall be designed for the conditions and stresses that they encounter during start-up, running, transient, shutdown or trip conditions.

Where the energy stored in rotating equipment cannot always be contained, the applicable risks shall be assessed and reduced to an adequate level in accordance with ISO 21789:2009, 5.8.15.2. Overspeed protection measures shall comply with the requirements specified in ISO 21789:2009.

14.10 Hydraulically operated safety equipment

Hydraulic oil system design shall ensure that oil degradation does not have an impact on the performance of isolating/emergency valves and control valves. The risk is associated with the build-up of varnish contaminants through the oxidation of the lube oil associated with high temperatures and pressures. The Contractor shall substantiate that adequate risk reduction is in place to prevent incorrect hydraulic oil system operation due to the build-up of varnish contamination where a common lube and hydraulic oil system is used in accordance with the document data sheet. This may include filtration, regular quality checks of the oil, functional testing, or the installation of a separated hydraulic system with a suitable medium, which is not subject to varnishing or fouling.

14.11 Fuel system 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 adequate risk reduction and shall be appropriately documented in accordance with the document data sheet.

14.12 Clutch

Where a clutch exists within the main shaft train of a combined cycle gas and steam turbine, adequate risk reduction shall be undertaken and, where necessary, mitigation factors and instructions introduced to reduce the possibility of clutch engagement that may create a hazardous situation.

In addition to the requirements of ISO 21789:2009, 5.8.13 and 5.8.17, the design of couplings and gearboxes shall take into account the potential for overload due to potential clutch engagement faults.

14.13 Functional safety

Functional safety requirements shall comply with the requirements of ISO 21789:2009, 5.20.1.

14.14 Hazardous material

The Contractor shall declare the usage of all hazardous materials and provide justification that a suitable, less hazardous alternative is not available in accordance with the document data sheet. All materials on site shall be labelled in accordance with the appropriate regulations. The Contractor shall keep an up-to-date record (inventory) of all substances held on site falling within the scope of the regulations controlling substances hazardous to health.

Exposure to hazardous substances shall, wherever possible, be reduced to as low as reasonably practicable by engineering means. Control measures shall ensure that exposure is at a minimum reduced to less than the appropriate exposure limit. The Contractor shall fulfil their obligations under all relevant statutory requirements and advise the Purchaser of their proposals for the containment, ventilation, transport disposal and decontamination of associated power plant.

All disposals of hazardous materials shall be carried out in accordance with the appropriate regulations.

14.15 Overspeed protection system testing

The Contractor shall document, in accordance with the document data sheet, required testing in the user manual to identify the extent of overspeed protection system checking that is necessary to demonstrate system function. This shall form the basis for a recommended overspeed test procedure and test frequency provided by the Contractor in their operations and maintenance manuals. Specifically, the Contractor shall advise whether and for what reason regular full physical overspeed (or proof test) trip testing is required.

There shall be the facility to automatically check as many elements of the overspeed protection system as possible without impacting operation. The Contractor shall provide automatic systems for overspeed testing that are selectable only when the power plant status and condition is correct in order to eliminate the risk involved with the manual change and re-setting of protection settings by the operator (see also 26.7.2.6).

Following an overspeed event in which the protection system functions correctly, the gas turbine package shall be capable of subsequent normal operation without the need for inspection. It is mandatory that all coupled equipment, including auxiliaries, whether electrically, mechanical or hydraulically or in any other way coupled, is designed to withstand the corresponding overspeed.

During an overspeed test personal access shall be prevented to the gas turbine enclosure and areas where potential exists for a loss of containment and/or an impact of uncontained parts from high speed rotating equipment.

14.16 Manual isolation features

All systems that require manual isolation as part of a safe system of work shall be provided with the facility to fit a lock or lockable device. The lock or lockable device shall typically be applied by the holder of the permit allowing work on the system.

14.17 Hazard identification and operability studies

The Purchaser, as owner/operator of the power plant, shall take responsibility for ensuring appropriate safety studies are undertaken during the contract stage including a site hazard identification (HAZID) study and a site systems hazard HAZOP study. The Contractor shall cooperate with the Purchaser during all phases of a project to identify and mitigate hazards and shall provide the Purchaser with applicable data and personnel, as agreed in the contract, as part of the Contractor’s scope of supply. Agreed mitigation measures shall be documented by the Purchaser in accordance with the document data sheet.

The HAZID study shall be undertaken for all the equipment in the scope of the contract and any other equipment outside this scope that may influence the results. Areas of concern shall not be restricted to main power plant items and shall include at least the following:

— access and lifting arrangements for small power plant items such as pumps/motors;

— use of vertical access ladders;

— adequate isolation of process fluids and fuels for maintenance (double isolation);

— rotating equipment guards;

— high temperature surfaces;

— high noise levels;

— emergency exits;

— protection systems (e.g. CO_2 release);

— platforms and rails.

NOTE ISO 17776 provides guidance on the tools and techniques for hazard identification.

The HAZOP study shall be undertaken covering all the applicable process equipment. Guidance on the application of HAZOP studies can be found in IEC 61882. Where a standardized design is offered by the Contractor and previously completed HAZOP assessments are available, these shall be made available as part of the study. The HAZOP process may then be restricted to any site specific requirements and any modifications to the standard design including elements of previous HAZOPs, where appropriate.

All risks identified shall be mitigated to achieve adequate risk reduction. Guidance on risk assessment is covered in ISO 21789:2009.

15 Measurement, language, identification and standardization

15.1 Units of measurement

Interface dimensions and information shall comply with the SI system of units, in accordance with ISO 80000-1 and its normative references. It is recommended that all project drawings, documentation, instrumentation, labels, operating and maintenance manuals, and all information within the distributed control system (DCS), including that shown on the HMI or engineering workstation, instrument gauges and instrument digital displays, shall be in SI units.

● If requested by the Purchaser, the HMI or engineering workstation units shall be imperial or dual SI and imperial as selected on the options data sheet.

● If requested by the Purchaser, the gauge units shall be imperial or dual SI and imperial as selected on the options data sheet.

● If requested by the Purchaser, the instrument digital display shall be imperial as selected on the options data sheet.

15.2 Language

15.2.1 General

The Purchaser shall identify and agree with the Contractor the language(s) for the various items identified in 15.2.2 to 15.2.5. The Purchaser shall identify and agree to the specific requirements for dual language. Where no language is identified and agreed the default shall be English.

15.2.2 Language for communication

The Purchaser shall identify to the Contractor the language(s) to be used for written and verbal communication until completion of the contract stage. This shall be identified on the information data sheet.

15.2.3 Language for documentation

The Purchaser shall identify to the Contractor the language(s) to be used for both paper and electronic documentation at all stages. This shall be identified on the information data sheet.

15.2.4 Language for HMI display screens

The Purchaser shall identify to the Contractor the language(s) to be used for all HMI display screens in the control room and all local panels. Requirements shall be identified on the information data sheet.

15.2.5 Language for labelling and signs

The Purchaser shall identify to the Contractor the language(s) to be used for all mechanical, electrical and control equipment labels and warning signs. This shall be identified on the information data sheet.

15.3 Equipment identification system, nameplates and labels

The Contractor shall propose and document, in accordance with the document data sheet, an equipment numbering and nomenclature system. The identifying system shall be used on all project drawings, specifications, instruction manuals, nameplates and labels and in all forms of communication with the Purchaser. Consistent and systematic method of equipment identification, nameplates and labels, employed throughout, should be used that identifies the equipment, instrument or component to drawings. The numbering system shall take into account a method of identifying equipment and component location relative to the overall system. The numbering system hierarchy should identify main equipment (gas turbine) or systems (fuel system), equipment type (mechanical, electrical), main components (valves, cabinet) and instruments.

NOTE The principles of ISO/TS 81346-3 can be used as a guide.

The Purchaser shall document, in accordance with the document data sheet, any variations required to the Contractor's proposal and any specific additional requirements.

Within a package boundary such as air compressors, there may be Contractor-specific identification as necessary at a component or instrument level. However, the package identification shall still comply with the overall numbering system. The Contractor shall ensure that the numbering system documentation has sufficient cross referencing to subcontractor numbering systems so that maintenance planning and spares identification within proprietary maintenance systems can be developed by the Purchaser.

All instruction plates, nameplates and identification labels shall show the component number. Instruction plates, nameplates and labels shall be fitted before commissioning on or adjacent to all apparatus requiring indication of operation, and shall be of such size as to be readable at operational levels.

● If requested by the Purchaser, the Contractor shall colour code piping systems (e.g. ISO 14726).

All valves shall be fitted with identification numbering and name labels.

Control and instrument panels, switchboards, motor control centres, junction boxes, etc. shall be fitted with identification labels in accordance with the nomenclature system.

Plates and labels shall be manufactured from durable materials that do not degrade in sunlight, heat or humidity and shall be securely fixed to the item described.

15.4 Standardization and interchangeability

The Contractor shall ensure that, as far as is reasonably practicable, similar equipment and components supplied under the project shall be standardized in terms of manufacturer, size range, rating, materials of construction, etc. Such standardization shall in no way compromise the suitability of each item to perform its required duty.

The primary aim of this requirement is to minimize the spare parts holding necessary to support the operation and maintenance of the gas turbine package. Standardization shall be applied by the Contractor where it promotes the following:

— reduction in variety of spare parts holdings;

— interchangeability of components;

— familiarization of maintenance and operating staff with power plant components;

— compatibility with existing equipment in service at the gas turbine package;

— where practicable, use of common instrumentation devices.

Standardization shall not involve "under-rating" of components.

16 Corrosion prevention, painting and finishing

16.1 General requirements

The Contractor shall ensure that, for all equipment, appropriate measures are ensured for long-term prevention of corrosion damage caused by external factors (principally atmospheric corrosion), and/or for maintaining functional or decorative effects on the surfaces of mechanical, electrical and structural components. The measures shall be adequate to meet the specified minimal life of the equipment and appropriately documented in accordance with the document data sheet. The Contractor shall deliver corrosion prevention solutions, painting and finishing to provide protection, based on the Contractor's experience, for the applicable environmental conditions.

Off-the-shelf equipment may deviate from this general specification providing that they satisfy the corrosion protection with the medium duration range as described in 16.2.1.

In case of special applications, painting might be required for the proper functioning of certain components (e.g. painting on the inside of water storage tanks). The functional requirements of such components shall govern in all cases where any discrepancies may arise between different requirements.

The Contractor shall provide documentation of all the colours used for all major items of equipment, in accordance with the document data sheet.

● If requested by the Purchaser, specific items of equipment shall be coloured by the Contractor as defined in accordance with the document data sheet.

16.2 Painting and coating

16.2.1 General

Painting systems applied on carbon or low-alloy steel of not less than 3 mm thickness shall be designed to have at least a durability range between 10 years to 15 years, the upper half of the medium durability range given in ISO 12944-1 and ISO 12944-2. Corrosion protection on steel parts below 3 mm thickness will be delivered according to the Contractor's experience and specification for the defined type of exposure. If additional requirements for the durability of paints exist, additional clarification shall be provided during the tendering phase. Surface preparation shall comply with 16.2.4.

● If requested by the Purchaser, variations to the above shall be implemented in accordance with the Purchaser's specification detailed as applicable in accordance with the document data sheet.

The assessment of surface cleanliness shall be in accordance with ISO 8501-1 or ISO 8501-2, i.e. the cleanliness of the surface is visually assessed. For coatings likely to be exposed to severe environments, such as water immersion and continuous-condensation conditions, physical and chemical methods of the various parts of the ISO 8502-series or equivalent shall be used.

16.2.2 Type of exposure

16.2.2.1 General

Characterization of the atmosphere on the basis of the corrosive agents present and their concentration shall be in accordance with the C codings described in ISO 12944-2:1998.

16.2.2.2 Indoor atmosphere

For interior environment fully enclosed facilities with no UV radiation

— interior C2 is applicable for rooms where condensation may occur,

— interior C3 is applicable for rooms with high humidity and some air pollution, and

— interior C4 is applicable for rooms with high humidity and moderate concentration of pollutants (mainly chlorides and sulfur dioxide) due to industrial/marine outdoor atmosphere.

16.2.2.3 Outdoor atmosphere

For surfaces exposed to outdoor conditions such as wind, rain, sunlight and others

— outdoor C3 atmosphere prevails in rural areas without significant contamination by corrosive agents,

— outdoor C4 atmosphere prevails in urban areas with significant industry and moderate concentration of pollutants (sulfur dioxide and/or chlorides) and coastal areas with moderate salinity conditions, and

— outdoor C5 atmosphere prevails as described in 16.2.2.4.

16.2.2.4 Outdoor industrial or marine very corrosive atmosphere

Marine very corrosive exposure means the atmosphere (i.e. high salinity – mainly chlorides) at sea as well as nearby the sea. The corrosion impact from sea depends on the distance from the sea, the topography as well as the predominant wind direction. A marine exposure may be present at a distance of 3 km to 5 km from any large body of seawater and contaminated fresh water (C5-M) in case of predominant winds from the sea.

In extreme cases 5 km may need to be exceeded.

Industrial very corrosive exposure reflects high humidity and the polluted atmosphere due to corrosive emissions (mainly sulfur dioxide) by regional, national or local industries (C5-I).

16.2.2.5 Acid and alkali exposure

Where atmospheric conditions exist, in conjunction with the presence of high concentrations of acids and alkalis, appropriate corrosion protection measures, including selection of coating, adequate ventilation and drainage, shall be taken (see Clause 6).

16.2.2.6 Insulated surfaces

Surfaces that are insulated where the material requires corrosion protection shall be suitably coated or painted prior to insulation for the durability required.

16.2.2.7 Condensation water, spray water and continuous water immersion

Surfaces exposed permanently to fresh or sea water (e.g. inside surface of water tanks) shall be of a suitable material that does not require protection or shall be suitably coated or painted to prevent corrosion for the durability required.

16.2.2.8 Other types of exposures

Other types of exposures may apply for tank internal coatings dependent on the tank contents or for buried exposures dependent on the soil conditions. For these exposures, suitable materials can be used that do not require protection or materials shall be suitably coated or painted to prevent corrosion for the durability required.

16.2.3 Visual assessment of workmanship of surface

ISO 8501-3 defines preparation grades of welds, cut edges and other areas with surface imperfections. The required preparation grade depends on the corrosivity category to which the equipment shall be exposed. The mentioned preparation grade shall be executed before starting the corrosion protective works.

P1 Light preparation is sufficient for C2 (low corrosivity) category.

P2 Thorough preparation is required for C3 (medium) and C4 (high) category.

P3 Very thorough preparation is required for C5-I/-M (very high) and Im1 to Im3 (immersed).

16.2.4 Preparation of the surface

The surface preparation prior to coating shall comply with ISO 12944-4.

Before starting the corrosion protection or paint work, all surfaces shall be free of any pollution that could prevent long-term efficient corrosion protection.

Surface defects such as rust or iron scaling or foreign matter (moisture, dust, grease, oil, destroyed coverings, old paints or coatings, etc.) shall be removed before the application of the coat.

The extent and thoroughness of cleaning and rust removal shall be appropriate to the paint or coating to be applied.

If blasting is required for the preparation of a surface, ISO 11124-1 and ISO 11126-1 shall be considered.

ISO 8504-1 shall be considered for the manual preparation of a surface.

16.2.5 Application procedures

The paint manufacturer's recommendation shall apply to the application method used.

Dry film thicknesses (DFT) of painting and coating shall be checked on

— the partial coating for partial coatings applied in factory or at site (primer or primer + intermediate coat), and

— the complete paint system applied in factory or at site.

Individual dry film thicknesses of less than 80 % of the nominal dry film thickness are not acceptable. Individual values between 80 % and 100 % of the nominal dry film thickness are acceptable provided that the overall average (mean) is equal to or greater than the nominal dry film thickness. Care shall be taken to achieve the nominal dry film thickness and to avoid areas of excessive thickness.

To ensure that the required minimal DFT has been attained, the average DFT shall be about 1,5 times the nominal DFT. If the paint system does not have the required minimal DFT those areas shall be marked and repainted.

Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces shall be in accordance with ISO 19840.

16.2.6 Paint materials

Paints that contain lead, cadmium, chromate or coal tar shall not be used. The paints shall be stored in safe buildings.

Health and safety data sheets shall be readily available for the paint products and shall be detailed in accordance with the document data sheet.

16.2.7 Galvanized coatings

Steel surfaces, which are hot dip galvanized, shall be welded strictly with uninterrupted welding to avoid the storage of acids in the crevices.

Hot dip galvanized coatings specifications and test methods shall comply with requirements specified in ISO 1461 and the coating shall comply with ISO 14713-2.

The coating shall be as uniform as possible, free from all defects that may hinder the use of the coated product.

16.2.8 Inspections and tests

The following test (done at random) shall be undertaken for all applicable equipment:

— manual checking of drying and hardness;

— checking visually for uniformity, coverage and for any damages and flaws and that the painting is free of pores, defects, bubbles and pinholes;

— measuring the DFT for conformity to requirements as provided in ISO 19840;

— checking the final colour according to Munsell code, RAL code or relevant code.

The adherence of the coats of paint is determined by crosscut in accordance with ISO 2409 or ISO 16276-2.

To control hydrolyse of ethyl silicate before application of next coat use the MEK test.

Inspection and test of buried and submerged coatings shall be agreed between the Purchaser and the Contractor for site specific requirements.

● If requested by the Purchaser, the inspection and test of buried and submerged coatings shall be undertaken in accordance with the Purchaser's requirements documented in accordance with the document data sheet or will be undertaken in accordance with the Contractor's standard procedures.

16.3 Galvanic effects

Special attention shall be paid to galvanic effects on areas where condensation or water entrapment may occur. The Contractor shall consider the available site information and specifications delivered by the Purchaser for the Contractor's selection of appropriate materials to meet the requirements.

17 Packing and transportation

17.1 Preparation

Gas turbines and their associated equipment shall be suitably prepared for the shipment in a manner appropriate to the type of transport, and clearly marked using internationally recognized symbols.

Where outdoor storage of equipment is permissible and/or due to the size of equipment no facility is available for indoor storage, a default period of 6 months shall apply to preservation of the applicable equipment for outdoor storage. Equipment not suitable for outdoor preservation shall be stored in a suitable facility under conditions that prevent deterioration/corrosion.

● If requested by the Purchaser that outdoor storage for periods > 6 months is required, the Contractor shall submit the procedure to be used, in accordance with the document data sheet, for the time specified by the Purchaser and the site conditions defined in Clause 6. Any variations required to the proposed procedure shall be documented by the Purchaser.

The Purchaser shall inform the Contractor about the storage facilities on site. The Contractor shall provide the Purchaser with the instructions necessary to ensure the integrity of the storage preservation after the equipment arrives at the job site and before start-up site. Requirements shall be in accordance with the document data sheet.

The Contractor shall define to the Purchaser, in accordance with the document data sheet, any precautions that need to be considered to avoid compromising the health and safety of personnel or the mechanical integrity of the equipment.

Documentation for transportation shall accompany the consignment and shall be the Contractor's responsibility.

The equipment shall be prepared for shipment after testing and inspection has been completed and approved by the Purchaser.

Exterior machined surfaces shall be coated with a corrosion inhibitor suitable for the transportation and installation environment and the total period of transportation, storage and installation.

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

The interior of the rotating equipment shall be clean, free of welding spatter scale, and protected from intrusion of scale and foreign objects.

Internal surfaces of bearing housings and carbon steel oil systems auxiliary equipment such as reservoirs, vessels and piping shall be coated with an oil-soluble corrosion inhibitor suitable for the transportation and installation environment and for the total period involved. Bearing assemblies shall be fully protected against the entry of moisture and dirt.

To prevent the ingress of dust or corrosive materials during shipment and storage, flanged and threaded openings shall be suitably covered.

Lifting points and lifting lugs shall be clearly identified. Masses, dimensions and centres of gravity shall be readily identifiable and, where necessary, procedures for the safe handling, loading and unloading of that package shall also be included.

The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with the item and serial number of the equipment for which it is intended. In addition, equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container. Auxiliary piping connections on the purchased equipment shall be permanently identified with the Contractor's connection table or general arrangement drawing.

A shipping list covering the major items to be delivered shall be provided including details of the size and weight of each separately shipped major item in accordance with the document data sheet.

If vapour-phase-inhibitor crystals in bags are installed in large cavities to enhance formation of a thin layer of volatile corrosion inhibitor to absorb moisture, the bags shall be attached to an accessible area for ease of removal and shall be suitable for the transportation and installation environment and for the total period involved. Where applicable, bags may be installed in wire cages attached to flanged covers and bag locations shall be indicated by corrosion-resistant tags.

17.2 Packing

The gas turbine and its auxiliary equipment (excluding those transported in their enclosures) shall be packed in such a manner to protect the equipment from water ingress, corrosion, impact damage or loss of components.

All lifts over 100 kg shall be marked on the outside of the packing case to show where the weight is bearing and the correct position for slings. Each crate or container shall have a general description of the contained equipment and the total weight if over 20 kg.

All packing cases shall have a general description of the contained equipment. The packing cases shall identify whether suitable for fork lift, orientation for lifting and storage (which way up) and if protection from weather is needed.

All spare parts shall be delivered in a condition suitable for storing without deterioration; where applicable, the shelf life shall be visible. The spare parts shipment packaging shall normally remain the property of the Purchaser unless they are special containers for special items, and marked as such, in which case they shall be returned to the Contractor.

If the packed component is subject to deterioration due to storage in a humid environment, the items should be protected by one of the following methods:

— sufficient amount of vapour phase inhibitor products (VpCI or VCI);

— spraying with oil mist;

— wrapping with oil impregnated cloth with recurrent inspections;

— dehumidifiers or drying agents with sufficient control of relative humidity.

17.3 Transportation

Packing and lifting plans shall be defined by the Contractor to prevent any significant acceleration or deceleration or vibration events that may damage the product.

The Contractor shall assess the risk of potential damage to rotors during transport and may select monitoring equipment to record excessive accidental transportation or handling of loads. The Purchaser shall advise any limitations for access and load capacity of transportation and cranes at their site that may affect packing for transportation in accordance with the document data sheet.

18 Gas turbine core

18.1 Design requirements

18.1.1 Life (hours and weighted hours, starts, cyclic events)

The Contractor shall state in the tender the design life of the gas turbine core expressed as a limiting number of weighted operating hours and starts for components not subject to planned replacement. Refer to 28.5 for planned replacement of components.

The Contractor's standard weighted calculation used for the design lives, quoted as hours and starts, shall be provided in accordance with the document data sheet including the algorithm and the associated parameters used.

The defined calculation shall, as a minimum, include the impact on life of the following:

— fast load/de-load between MCO and MCR;

— trip at any power level between MCO and MCR;

— operation on liquid fuel;

— normal start;

— fast start.

The minimum design life of components or modules subject to replacement at planned maintenance intervals shall be 25 000 weighted hours at MCR including 625 normal fired starts. The minimum interval between planned inspections shall be 8 000 weighted hours. The replacement of parts at planned inspections before 25 000 weighted hours may be undertaken provided this is taken into account in the RAM assessment values and any cost implications are defined.

The minimum design life of components or modules not subject to planned replacement shall be 100 000 weighted hours at MCR and 2 500 fired starts after which inspections may be required before the life of some equipment can be extended.

The above criteria exclude consumables.

● If requested by the Purchaser, the Contractor shall state on the information data sheet additional design life extensions available based on positive experience. This shall be expressed as the additional operating hours and additional number of starts potentially available.

18.1.2 Mechanical design shaft power limitations

The gas turbine rotor(s), coupling(s) and shaft(s) shall be designed to transmit/withstand the following:

— the maximum power that the gas turbine can deliver within the design operating range;

— the peak power at any defined peak loading condition;

— any over-torques during start-up and acceleration;

— short circuits torque due to a full line to line short circuit of the generator.

Where the short circuit torque from a full line to line short circuit of the generator cannot be absorbed by the applicable equipment, a torque limiting device shall be installed in the drive train to ensure the torque does not damage/exceed the capacity of the equipment.

18.1.3 Radial and axial clearances and control

The gas turbine radial clearances shall be designed for all normal transient operations such as starts, shutdowns and trips without causing damaging contact between rotor blades and casings and stator blades and rotor that would lead to the gas turbine core being removed from service. Under some extreme conditions, such as successive failed starts, the radial clearances may be reduced to an unacceptable level. The supporting information regarding the impact of initiating further starting sequences and recommendations such as barring operation shall be provided in the operating manual.

Where there is a high probability of a limiting condition being reached on radial clearances following successive failed starts, a protective measure, such as a start inhibit, shall apply until the limiting condition has abated.

Where the motive force for barring (see 30.1) fails, allowing rotor distortion and a rotor lock-up to occur, the operating manual shall detail the actions to be undertaken.

Where there is the potential for blade-casing contacts during commissioning, the commissioning manual shall state the action necessary to limit such occurrences and the subsequent action that shall be taken. The Contractor shall describe in the operating and maintenance manual the procedure for rotor positioning, alignment to generator and positioning of vane carriers to the rotor. The Contractor shall describe the cold position of the rotor relative to the rotor theoretical centre line position in the operating and maintenance manual.

18.1.4 Compressor

18.1.4.1 Compressor blading damage tolerance

Impact or corrosion/erosion damage can occur in operation to the initial stage of the gas turbine compressor that can cause premature failure. The acceptable damage criteria shall be documented to the Purchaser by the Contractor for the first stage compressor rotor blades in accordance with the document data sheet.

Allowance shall be included in the first stage compressor design, taking into account the materials and/or coating used and the applications for which the gas turbine is put to use, such that the minimum critical defect size will permit sustained operation.

18.1.4.2 Rotating stall

The compressor and its associated equipment (including bleed valves and variable stator vanes) shall be designed such that the strength of rotating stall excitation on compressor blading does not result in significantly reduced component life. The stall shall not excite significant resonance of the rotor that would lead to significant contact damage other than local rubbing. These requirements prerequisite that filters and washing equipment and their operation and maintenance are according to the Contractor's recommendation.

18.1.4.3 Bleed or blow off valve and actuation

The bleed or blow off valve and body materials shall be selected to minimize corrosion and sticking of valves in service. Actuator rating shall be sized to overcome resistance due to corrosion.

18.1.4.4 Corrosion protection

Where the presence of corrosive atmosphere at the compressor inlet cannot be avoided, the compressor blading shall be protected from corrosion by use of corrosion-resistant blade materials or by application of corrosion-resistant coatings. Where required to prevent erosion of blade coatings during operation or compressor washing, procedures for coating used for the initial stages of the compressor blades shall have sufficient erosion resistance to prevent premature deterioration of the coating.

18.1.4.5 Compressor blade rub tolerance

The design of compressor rotor and stator blades shall have features such as sufficient tip clearance, abradable seals, blade shrouds or tip fences, etc. to minimize the potential for blade tip contact that can lead to blade tip damage that limits the performance of the gas turbine and/or causes damage that can initiate blade tip cracks leading to blade failure.

18.1.5 Turbine

18.1.5.1 Turbine coatings for oxidation, corrosion and thermal barrier

Where coatings are applied to the turbine components for protection of the base material from the hot gas environment and it is planned that the component be repaired by coating removal and replacement at maintenance outages, details of the repair procedures shall be documented.

18.1.5.2 Planned component repair and repair status

Where it is planned that turbine components are repaired, according to the Contractor's maintenance strategy and planning document, the Contractor shall provide a list of these components, including the expected exchange interval for reconditioning/repair and the expected replacement interval in accordance with the document data sheet.

The Contractor shall identify in its tender response in the information data sheet whether it employs internal cooling passage coatings and whether these coatings are repairable.

The Contractor shall identify in its tender response in the information data sheet whether it employs drilled film cooling holes on coated components and confirm whether the repair process completely unblocks re-coated film cooling holes.

18.1.5.3 Turbine cooling systems blockage

The design of the turbine air cooling supply system and the selection of materials shall ensure that the internal cooling passages and the small diameter holes in inserts or film cooling of cooled components are not blocked by scaling/corrosion particles formed within the cooling air supply system in the time between major services. Where the potential exists for blockage, features that allow the inspection of such areas shall be provided. Measures taken shall include allowances in passage sizing, suitable inlet filtration and material selection to minimize scaling/corrosion.

18.1.6 Combustor

18.1.6.1 Combustion stability and control

Lean combustion systems shall be free of unacceptable damage produced by the following mechanisms while operating between synchronization and MCR, allowing for site atmospheric condition variation and site fuel quality:

— thermo-acoustic pulsation;

— flashback.

Unacceptable damage shall be defined as that which requires an unplanned maintenance outage and combustor components to be repaired/replaced before the scheduled maintenance outage and/or significant loss in the reparability of components.

Flashback is defined as the temporary movement of the combustion flame front from its normal position to close to the fuel injector or burner. The risk from flashback is the ignition of a stable flame attached to or near the burner.

The Contractor shall provide documentation, in accordance with the document data sheet, covering

— description of active instability or pulsation control system, where installed, and

— description of combustion auto-tuning capability, where installed.

18.1.6.2 Ignition

The design intent of all the ignition and flame detection equipment necessary for starting the gas turbine shall achieve the overall requirements for start reliability stated in information data sheet 8, 13.1.

The installation of igniter transformers and routing of ignition cables shall be well clear of the hot gas casings such as to prevent burning or over-heating. Cabling support brackets shall be positioned and designed to prevent damage to ignition cables during operation.

Flame detection and protection requirements are given in 26.7.2.1.

18.1.6.3 Fuel nozzle assembly

Burners shall be calibrated so that replacement of individual burners shall be possible with minimum tuning of the fuel supply parameters.

The fuel nozzle assembly and fuel delivery system materials shall be selected to prevent internal scaling, which may lead to burner blockage, when operating on natural gas complying with the Contractor's fuel specification.

Where material choice does not prevent internal scaling, other mitigation measures such as internal coatings to prevent fuel nozzle assembly blockage shall be considered.

Fuel nozzle assembly design shall be such as to avoid burner malfunction and blockage due to the build-up of deposits at the burner exits.

Where necessary to prevent such occurrences with fuels to be utilized, the Contractor shall define the operation regions to be avoided to prevent such build-up or define the additional maintenance activities required to remove the build-up.

The Contractor shall supply in operating manuals measures to detect possible scaling and the actions required for inspection and cleaning in maintenance manuals.

18.1.6.4 Combustor heat shields or liners

Inspection of the combustion chamber shall be possible without removing major casings.

Where combustor heat shield or liners are utilized and where a residual risk of loss of parts is credible and the consequential damage may lead to a forced outage, suitable monitoring shall be implemented to provide gas turbine warning and trip functions.

Where burner temperatures are not monitored directly to assist with the identification of potential burner problems, the relationship between gas path temperatures and the burner temperatures shall be provided in the operation manual or the control system.

Measurement of combustor pressure pulsation or combustor casing vibration and protection is given in 26.7.2.7.

18.1.7 Casings

18.1.7.1 General

The gas turbine compressor, turbine and exhaust casings shall be designed and materials selected such that the life requirement defined in 18.1.1 is achieved without replacement. Casings shall be designed to eliminate the need for rotor alignment due to casing distortion between planned major inspection intervals.

Where adjustments are necessary to control gas turbine clearances, vane carriers or adjustable vane support rings shall be provided to allow adjustment of the stator to rotor clearances during maintenance.

The design of casing joints, the associated fasteners and their clamping loads shall ensure that leakages do not affect safe operation and integrity of gas turbine components and adjacent equipment under all start-up, operating and shutdown conditions.

18.1.7.2 Exhaust casings and diffusers

Exhaust casings/diffusers shall be designed to eliminate the need for repair between inspection intervals. Where repairs are necessary at an inspection interval, the repair should not require an extension to the planned outage duration.

18.1.7.3 Casing insulation

● If requested by the Purchaser, and available as an option, insulation shall be available over the hot external surfaces of the gas turbine to, where applicable, improve efficiency, reduce the cooling requirements of the ventilation system and reduce potential for casing distortions. The insulation shall be resistant to hydrocarbon fluid or lube oil contamination of fire resistant material to reduce the risk of fire and, where applicable, designed for ease of removal for maintenance purposes.

18.1.8 Rotor

18.1.8.1 Materials

The gas turbine rotor component materials shall be selected for the applicable duty and stresses involved and to prevent failures due to aging effects (creep, embrittlement, loss of strength) during the designed cycle life of the component.

● If requested, the Contractor shall supply forging specific material properties certification for supplied rotor components to the Purchaser in accordance with the document data sheet.

18.1.8.2 Rotor seizures

The combination of the gas turbine design, control system protection and the specific guidance from the operating manual shall prevent occurrence of rotor seizure from foreseeable operating and environmental conditions.

18.1.8.3 Forced cooling

● If requested by the Purchaser, and available as an option, forced cooling shall be offered by the Contractor to shorten the time taken to cool the unit during shutdown and allow early access to the gas turbine for maintenance inspections. The Contractor's forced cooling technique shall not cause rotor seizure and/or significant damage to the gas turbine.

18.1.8.4 Rotor thermal response

The design of the gas turbine rotor, bearings and its support structure shall ensure that the rotor vibration resulting from operating thermal transients does not lead to repeated loss of availability through load trips or loss of load through other protective events such as load shedding. The rotor thermal response shall also comply with the rotor vibration quality requirements of 18.2.

The rotor thermal response shall not limit the number or frequency of starts beyond the instructions given in the operating manual.

18.1.9 Rotor standstill corrosion protection

For details of requirements refer to 20.9.

18.1.10 Rotor overspeed capability

The gas turbine rotor(s) shall have a maximum speed (over-speed) capability that exceeds (by a defined margin) both the predicted over-speed due to instantaneous loss of load or coupling failure and its physical overspeed test speed. The Contractor shall state the margins for both these cases in the information data sheet. The gas turbine rotor(s) shall be capable of reaching the speed due to loss of load without the overstressing of rotating parts or incurring any other component damage.

The overspeed margin shall take into account the potential for overshoot that may occur during a sudden loss of load such as generator fault or similar electrical system fault (see 14.15 and 26.7.2.6 for overspeed protection and testing requirements).

● If requested by the Purchaser, the Contractor shall provide justification of the overspeed margin capability in accordance with the document data sheet.

18.1.11 Vibration and dynamics

18.1.11.1 General

● If requested by the Purchaser, the Contractor shall provide a lateral analysis to identify the resonant frequencies of the complete power generation package. The Purchaser shall provide all necessary information from other equipment suppliers to support the analysis. Documents shall be provided in accordance with the document data sheet.

The complete rotor system for the gas turbine package shall be suitable for the specified operating speed range, including any starting speed hold-point requirements of the train. Details of all undesirable speeds shall be submitted to the Purchaser. This shall be documented in accordance with the document data sheet and preferably should be programmed into the control system in order to avoid the potential for a dwell at any undesired speed ranges if increasing speed is not performed automatically. Where different equipment on the main drive shaft train is the responsibility of the Purchaser, the Purchaser shall take responsibility for determining the resolution of any associated problems, supported by the Contractor where applicable.

Special consideration shall be given where the supporting foundation differs from the standard design and if any specific external forces exist as defined by the Purchaser and documented in accordance with the document data sheet.

18.1.11.2 Lateral vibrations

An analysis of the lateral vibration characteristics of the gas turbine package shall be conducted for the first of its kind or if a coupling or a bearing support has been modified. Flexible couplings or slender intermediate shafts allow the lateral analysis to be carried out separately for the individual components.

ISO 21940-31 establishes methods to assess the modal sensitivity of machines to unbalance and these methods shall mainly be applied in the design analysis phase. Gas turbines are referred as Type II machines in ISO 21940-31, which also gives the required frequency separation margin for vibration response peaks (also referred to as “critical speed”, “mode” or “resonance”). It applies to lateral vibrations based on unbalance response calculations or on measurements from the same or a similar machine. A high modal sensitivity according to this method (designated with range D or E) is a warning, indicating that at least one of the following actions is recommended:

— shifting either the exciting frequency or the critical speed;

— increasing the damping;

— performing a stress response analysis demonstrating that the resonance in question has no adverse effect on any part of the shaft train.

18.1.11.3 Torsional vibrations

The Contractor shall perform an analysis of the torsional vibration characteristics of the power generation package in accordance with the document data sheet. A minimum separation margin of 10 % is recommended between each torsional natural frequency and any possible torsional excitation frequency within the operational speed range of the gas turbine package. If this recommended margin cannot be attained, the Contractor shall evaluate the separation margin achieved between each torsional natural frequency and identified excitation frequencies in accordance with the requirements defined in ISO 22266-1.

18.2 Vibration acceptance limits

18.2.1 General

Machine vibrations can be measured using radial shaft vibration probes measuring the movement of shafts in bearings or seismic vibration probes measuring the movement of casings. ISO 7919-1:1996 and ISO 7919-4:2009 give guidelines for applying evaluation criteria for radial shaft vibration probes, ISO 10816-1 and ISO 10816-4:2009 give guidelines for applying evaluation criteria for seismic vibration probes.

Vibration monitoring shall be provided in accordance with 26.2.6.

18.2.2 Measurements on rotating shafts

Where tests are undertaken at the manufacturer's factory, either loaded or unloaded, under steady-state conditions and at rated speed, vibrations shall not exceed that shown in Formula (13):

$$A(p\text{-}p) = 6300/\sqrt{N}\ \mu m \text{ (e.g. 70 \% of the ISO 7919-4:2009 Zone B limit)} \quad (13)$$

Vibrations during installation tests, running under steady-state operating conditions at rated speed over the full load range, shall not exceed that shown in Formula (14):

$$A(p\text{-}p) = 7200/\sqrt{N}\ \mu m \text{ (e.g. 80 \% of the ISO 7919-4:2009 Zone B limit)} \quad (14)$$

where

A(p-p) is the magnitude of unfiltered vibration, µm peak-to-peak;

N is the speed in revolutions per minute.

Where applicable, the alarm and trip vibration levels shall be derived in accordance with ISO 7919-4:2009 taking into account the example provided in ISO 7919-4:2009, Annex B and the transducer arrangement.

Where the outputs from a pair of orthogonal transducers at the measurement plane are used to derive the maximum vibratory displacement in the plane of measurement (see Method C of ISO 7919-1:1996, Annex B), lower values should be used which are dependent on the shaft orbit. As a general guideline, the ISO 7919-4:2009, Annex A levels should be divided by a factor of 1,85.

For single-shaft combined cycle power generation packages in which a gas turbine is coupled to a steam turbine and/or generator, the gas turbine shall comply with this clause. For steam turbine and generators ISO 7919-2 or ISO 7919-3 should be used.

The Contractor shall define in the operating manual any vibration trip multiplier, inhibits or time delays defined in the turbine control system during start–up, including the start and finish speed which applies, and during normal running, where applicable. Where a trip multiplier is used, the multiplier used shall not exceed the dynamic range of the monitoring channel otherwise alarms will not trigger.

Gas turbines with rolling element bearings are excluded from measurements on rotating shafts in accordance with ISO 7919-4:2009 vibration criteria.

18.2.3 Measurements on non-rotating parts

Where tests are undertaken at the manufacturer's factory, either loaded or unloaded, under steady-state conditions and at rated speed, vibration shall not exceed that shown in Formula (15):

$$6{,}51 \text{ mm/s rms (e.g. 70 \% of the ISO 10816-4:2009 Zone B limit)} \quad (15)$$

Vibrations during initial installation tests, running under steady-state operating conditions at rated speed over the full load range, shall not exceed that shown in Formula (16):

$$7{,}44 \text{ mm/s rms (e.g. 80 \% of the ISO 10816-4:2009 Zone B limit)} \quad (16)$$

The alarm and trip vibration levels shall be derived in accordance with ISO 10816-4:2009 taking into account the example provided in ISO 10816-4:2009, Annex B.

For single-shaft combined cycle power generation packages in which a gas turbine is coupled to a steam turbine and/or generator, the evaluation of the gas turbine vibration shall comply with this clause, but that of the steam turbine and generators shall be in accordance with ISO 10816-2 or ISO 10816-3, as applicable.

18.3 Balance quality

18.3.1 Balance planes

The Contractor shall provide features, where practical, to allow site trim balance of the rotors *in situ* without disturbing major casings.

18.3.2 Balancing general

Rotors shall be balanced in accordance with the following procedures.

— Rotors with rigid behaviour shall be balanced at low speed in two planes in accordance with ISO 1940-1:2003. If the first flexural critical speed exceeds the maximum operating speed by at least 50 %, the rotor can normally be considered rigid for balancing purposes.

— Rotors with flexible behaviour require multi-plane balancing at high speed or low speed balancing in stages during assembly in accordance with ISO 11342:1998. Rotors that do not satisfy the rigid rotor definition can be considered flexible for balancing purposes.

— When a rotor with a keyway is balanced, the keyway shall be filled with a fully crowned half key, in accordance with ISO 21940-32.

— The Contractor shall submit the balancing procedure for information in accordance with the document data sheet.

The Contractor shall advise the Purchaser if the procedures used differ from the above.

● If requested by the Purchaser, balancing results shall be reported, indicating which method has been used, balancing weights or other corrections made (magnitude and location), residual unbalance and permissible residual unbalance.

18.3.3 Low speed balancing

Major parts of the rotating element, such as the shaft, balancing drum, impellers or disks, shall be individually dynamically balanced before assembly in accordance with ISO 1940-1:2003, Quality grade G 2.5.

The assembled rotating element shall be multi-plane dynamically balanced in accordance with ISO 1940-1:2003, Quality grade G 2.5.

The Contractor shall advise the Purchaser if the procedures used differ from the above.

18.3.4 High speed balancing

When required, high speed balancing shall be performed in accordance with procedures described in ISO 11342:1998.

Acceptance criteria for high speed balancing shall be in accordance with either

— residual unbalance criteria in accordance with ISO 11342:1998, Quality grade G 2.5, or

— pedestal vibration derived in accordance with the methods described in ISO 11342:1998, 8.2.5 using values of $K0$, $K1$, $K2$ that have been validated to achieve the vibration acceptance limits defined in 18.2.

The Contractor shall advise the Purchaser if the procedures used differ from the above.

The Contractor shall provide, in accordance with the document data sheet, the acceptance criteria for the balancing procedure used.

Where the rotor train is balanced *in situ* the documentation of this balance shall comply with ISO 21940-13.

18.4 Bearings and supports

Where a gas turbine package is designed to be maintained only at site, the bearing pedestals shall be designed to allow inspection of bearings during major maintenance outages. The specified normal operating temperature of the bearing shall have a margin sufficient to prevent degradation of the bearing material and reduce bearing life under the maximum range of operating conditions. Bearing temperature measurement and protection requirements are given in 26.7.2.2.

Where tilting pads are used for thrust bearings at light thrust loads there is the risk of poor formation of oil wedge and oscillation of loading between the active and inactive bearings. The Contractor shall provide positive thrust to the active bearing for steady-state operation between synchronization and MCR or the Contractor shall demonstrate thrust bearing will remain stable under low thrust operation.

The lining of non-shell type bearings shall be reparable.

18.5 Modified cycles

18.5.1 General

The Contractor shall advise in the tender, if applicable, any alteration to the standard gas turbine thermodynamic cycle for power enhancement or emissions control such as recuperation, exhaust gas recirculation, re-heating or inter-cooling that modifies the core gas turbine from its simple cycle configuration and any modification to the equipment life or maintenance requirements. The Contractor shall provide the experience base for the cycle modification in the tender. Documentation shall be in accordance with the document data sheet.

18.5.2 External air coolers and direct steam cooling

The Contractor shall document, in accordance with the document data sheet, all the external devices such as motor driven fans and heat exchangers that are a fundamental part of the gas turbine (rotor and casing) cooling system. The cooling system shall include internal component cooling, rotor cooling, hot bearing casing/supports cooling, combustor casing external cooling and exhaust casing external cooling. Where the failure of such external devices would cause the gas turbine package to trip, the Contractor shall ensure a high reliability is maintained either through device redundancy or through the use of high reliability devices.

● If requested by the Purchaser, redundancy shall be offered for any external cooling fan device required for the cooling systems listed above.

The Contractor shall document, in accordance with the document data sheet,

— all components in the gas turbine that use steam as primary cooling media,

— the operating experience with steam cooled components, and

— whether the components are initially air cooled and then steam is added later in the start sequence.

The Contractor shall provide all unique requirements for the start-up, shutdown and purging sequences using steam cooling in the operating manual (see 11.8). The requirements for the supply of steam shall be defined in the documentation for 6.3. The operating manual shall also contain any specific protections required for these systems. Requirements for steam purity and steam quality monitoring shall be provided.

The specific maintenance requirements shall be provided in all maintenance manuals (see 28.10).

19 Gearboxes and couplings

19.1 Load gearbox

The load gear design, balancing, testing and application shall comply with ISO 6336-1 including all parts listed in the normative references, ISO 13691, API 613, AGMA 6011-I03, AGMA 6011-J14 or AGMA 6123-B06. The Contractor shall specify the design standard used and the manufacturer.

The minimum power ratings of load gears shall be at least equal to the maximum power rating of the gas turbine or the gas turbine shall be limited by a power limiting control device at maximum load gear power rating.

The design of the load gear shall, without critical speed and bearing instability problems, allow the gas turbine to operate from its maximum output down to its minimum load capability.

The Contractor shall specify the gear rated power at the gear service factor and rated output speed and the efficiency at MCR.

19.2 Auxiliary gears

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

Auxiliary gears shall comply with ISO 6336-1 or an alternative standard which provides the equivalent load carrying capacity and shall be rated for at least 110 % of the maximum power transmitted.

19.3 Balancing and vibration

The main and auxiliary gearboxes shall operate through the complete load and speed range with a stable vibrational behaviour. The balancing shall be performed in accordance with ISO 1940-1:2003, Quality grade G 2.5 recommended for gas turbines in Table 1 of the standard to ensure vibration levels from the gears do not have an adverse effect on the gas turbine vibration levels. If the Contractor has experience that balancing to G6.3 is acceptable as recommended by ISO 1940-1:2003, Table 1 for gears and any effect on gear vibration levels will not affect the gas turbine, this level may be used.

Where tests are undertaken at the gear manufacturer's factory, either loaded or unloaded, under steady-state conditions and at rated speed, vibration shall not exceed

— casing vibration ≤ 2,9 mm/s rms: 10 Hz to 2,5 kHz, or

— casing acceleration ≤ 4g Peak: 2,5 kHz to 10 kHz, or

— shaft vibration ≤ 2782/√N (max 50) µm peak-to-peak; *N* = maximum continuous speed, in revolutions per minute.

If the above levels are not achieved at the gear manufacturer's factory, justification shall be given that the levels achieved will ensure that the levels specified for the installation tests shall be achieved.

Vibrations during installation tests, running under steady-state operating conditions at rated speed over the full load range, shall not exceed

— casing vibration ≤ 4,5 mm/s rms: 10 Hz to 2,5 kHz, or

— casing acceleration ≤ 6 g Peak: 2,5 kHz to 10 kHz, or

— shaft vibration ≤ 4800/√N (maximum 50) µm peak-to-peak; *N* = maximum continuous speed, in revolutions per minute.

The alarm and trip vibration levels should be derived based on the principles in ISO 7919-4:2009 or ISO 10816-4:2009, as applicable, taking into account the example provided in ISO 7919-4:2009, Annex B or ISO 10816-4:2009.

Vibration monitoring shall be provided in accordance with 26.2.6 for the main drive and auxiliary gearboxes associated with the main drive train.

● If requested by the Purchaser, small auxiliary gearboxes not associated with the main drive train shall be provided with vibration monitoring and details provided in accordance with the document data sheet.

19.4 Main drive shaft couplings

19.4.1 General

Main drive couplings are used to transmit load from the gas turbine package to the driven equipment either directly or indirectly via a gearbox.

Couplings can be either of rigid or flexible design as specified by the Contractor for the given application.

The coupling shall be selected based on the site rated power at MCR and shall be capable of transmitting this maximum steady-state torque, cyclic torques, and the maximum transient torques under all conditions of angular misalignment, axial displacement, speeds, over-speeds and temperatures, simultaneously without damage, to which it will be subjected in service. A minimum service factor of 1,2 shall be applied to the MCR.

Angular misalignment and axial displacement capabilities shall take into account the following.

— The maximum applicable potential offsets associated with all casing and ambient temperatures variations during all running, start-up and rundown conditions.

— Movements where the gas turbine package/power generation package structure is 3 point mounted or mounted on flexible supports where environmental loads and/or support structure movements may cause deflections at the coupling locations.

When flexible gear type couplings are employed they shall be designed for continuous lubrication.

Flexible couplings utilizing dry element diaphragms shall include features to prevent the centre spool piece from dangerous movement or to prevent further damage to equipment or personnel in the event of a diaphragm failure. This device can be integrated into the coupling design or form part of the coupling guard.

19.4.2 Main drive flexible couplings – speeds not exceeding 4 000 r/min

Gear and diaphragm coupling shall comply with the requirements of ISO 14691 or an alternative design documented by the Contractor in accordance with the document data sheet.

The coupling shall be capable of accepting the expected magnitude of momentary torques, resulting from generator short-circuit torques without damage and other foreseeable fault conditions, which the coupling is required to survive without the loss of integrity but possibly with some damage.

Where equipment in the drive train cannot withstand the momentary over-torque from a generator short-circuit without incurring damage, the coupling shall incorporate an over-torque device that prevents an unacceptable magnitude of torque reaching the said equipment (see 18.1.2).

19.4.3 Main drive flexible couplings – speeds exceeding 4 000 r/min

Gear and diaphragm coupling shall comply with the requirements of ISO 10441:2007 or alternative designs specified by the Contractor. Where applicable, the Purchaser shall document any variations required to the Contractor's specification in accordance with the document data sheet.

The coupling shall be capable of accepting the expected magnitude of momentary torques, resulting from generator short-circuit torques without damage and other foreseeable fault conditions, which the coupling is required to survive but possibly with some damage. For cases where protection is required from a momentary over-torque from a generator short-circuit, protection shall be provided by the incorporation of an over-torque device in the low speed coupling associated with the generator shaft (see 19.4.2).

19.4.4 Quill shaft main drive flexible couplings

Quill shaft coupling shall comply with the requirements of ISO 10441:2007 or an alternative design documented by the Contractor in accordance with the document data sheet.

Where equipment in the drive train cannot withstand the momentary over-torque from a generator short-circuit without incurring damage, the shaft system shall incorporate an over-torque device that prevents an unacceptable magnitude of torque reaching the said equipment (see 19.4.2).

19.4.5 Rigid couplings

The bolting between rigid coupling flanges shall be capable of transmitting the maximum required fault torque without dependence on flange-face friction or creating stepping of the bolt diameter.

Bolts for spigoted flanges shall have a diametral clearance of 0,000 mm to 0,100 mm. Bolts for non-spigoted flanges shall be of the body bound style and shall be through fitted into reamed holes, with the assembly's diametral clearance ranging from 0,00 mm to 0,038 mm.

Each bolt, each nut and other similar components that require removal for normal field disassembly of the coupling shall be mass balanced individually to a total tolerance of 0,05 % of the component's mass or 0,1 g (0,003 5 oz), whichever is greater.

Where a rigid coupling is used, the design shall take into account the effect of adjacent shaft catenary such that correct alignment is achieved and stresses imposed by adjacent shaft catenary are acceptable and do not lead to fatigue in the coupling components.

19.4.6 Over-torque devices

Over-torque devices shall be capable of operating without damage to the coupling when activated and during rundown of the rotating equipment. The operating mechanism of the over-torque device shall be capable of being reset or components designed to fail capable of being replaced without changing other components of the coupling.

The setting at which the over-torque device operates shall be such that incorrect operation does not occur due to start-up and cyclic loading causing slippage or shear pin fatigue.

Where shear pins are used, the design shall be such that as far as practical all the pins share the load equally and have the same material properties and dimensions and the pin design/dimensions are proven by batch testing. The design shall be sufficiently robust to allow efficient operation after a minimum of 20 over-torque failures, with only the shear pins needing replacement. The design shall be such as to allow easy withdrawal and replacement of failed pins.

The coupling design incorporating the over-torque device shall be capable of allowing free running of one drive flange with respect to the other for a minimum period of 24 h after operation.

19.4.7 Coupling guards

Each coupling should have a coupling guard to prevent access to the danger zone by personnel during operation of the equipment train. Coupling guards should be designed to limit windage loss and heat generation and have features that allow access for checking of alignment.

Guards shall comply with the requirements of ISO 10441:2007, Annex H as applicable or an alternative design documented by the Contractor.

Guards for continuously lubricated coupling shall comply with ISO 10441:2007, H.5 or an alternative design documented by the Contractor and shall be designed to minimize the accumulation of foreign material and sludge.

Where the coupling guard is used in a potentially hazardous area, consideration shall be given to the use of non-sparking materials in the construction of the guard.

20 Air inlet system

20.1 General

Gas turbines require clean air for combustion and 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, maintenance costs and performance degradation. Air quality is particularly important with respect to gaseous contaminants, which cannot be removed by filtration.

● The Purchaser shall select on the options data sheet the basic type of filter element based on the Purchaser's experience. The Contractor's tender shall be based on the requested system.

The Contractor shall recommend a filter assembly design taking into account

— the basic type of filter selected by the Purchaser,

— the economic priority and element life ranking supplied by the Purchaser (see above option),

— the air quality information in accordance with Clause 6,

— the Purchaser option selected for high efficiency particle arrester (HEPA) filters, where selected (see 20.2),

— the option selected for filter element area increase (see 20.2),

— the potential for the presence of hot, dust bearing winds that can rapidly cause contamination of the filter system leading to premature shutdown, and

— the location and area available for the installation of the filter assembly.

The recommendation shall consider the use of pulse and static filter systems utilizing water removal features and HEPA filter elements, where applicable, while taking into account the location and area available for the installation of the filter assemble. The recommended filter design shall be defined in accordance with the document data sheet.

20.2 Air filter

● The Purchaser shall provide, via the options data sheet, the prioritization of key economic priority and the element life rankings of the gas turbine output, gas turbine efficiency, system and system maintenance cost to assist the Contractor in the optimized selection of air inlet filter for economic benefit.

Filter bank size (area) affects both filter life and air velocities and thus filter pressure drop. There is a benefit for accepting a higher initial capital cost for lower through life costs, therefore the Purchaser may wish to define the increased filter area.

● If requested by the Purchaser that a percentage over capacity shall be used for the filter bank area, the Contractor shall apply this over capacity to the normal rated maximum flow when sizing the filter.

Rain and/or snow hoods shall be provided where conditions of rain or snow may exist that will adversely affect the performance of the filter assembly. The provision provided shall be stated in the information data sheet.

Trash and/or insect screens shall be provided where there is the potential for trash or insects at the inlet to the filter with the potential for adversely affecting the performance of the filter. The provision provided shall be stated in the information data sheet.

● If requested by the Purchaser, the Contractor shall install HEPA filters to EN 1822-1.

● The Contractor shall provide generic efficiency test data in accordance with EN 1822-5 or EN 779 for the filter stages and generic wet burst pressure to ASTM D3786 or ISO 13938-1 where available in accordance with the document data sheet.

The Contractor shall supply the following information on the information data sheets:

— filter surface media area and number of elements (per filter stage);

— dust holding capacity (per filter stage);

— filter class in accordance with EN 779 and EN 1822-1 for classification on static filtration;

— filter class in accordance with ASHRAE 52.2 for MERV classification on pulse cleaning filtration;

— estimated filter life;

— confirmation that hydrophobic (water resistant or water shedding) material is used and stage fitted;

— confirmation that the filter design intent is to collect and drain water as a coalesce and the stage used for this function;

— filter house overall pressure drop (mbar) new at MCR rated flow.

20.3 Inlet filter house

The air intake filter house, whether it is a static or a pulse cleaned variant, shall be of modular design using standard size filter elements irrespective of supplier. The Contractor shall design the height of individual filter house(s) to minimize the mechanical handling risk to personnel removing and installing large filter elements. This design requirement shall, where practicable, minimize the need to work at height from access platforms and ladders. The filter house shall be designed to minimize the amount of construction work at site. The roof portions of any filter house or plenum exposed to the weather shall have a slope or fall towards the outside edge(s) to avoid water collection.

Lighting shall be supplied for the internal working areas of the filter house with a normal intensity of 300 Lux in accordance with EN 1837, walkways and access routes shall have a minimum illumination of 20 Lux. Emergency lighting shall be supplied on egress routes in accordance with EN 1838. Light switch locations shall be located at the point of access to the filter house.

The lower filter element(s) surface in any filter house shall be of sufficient distance above the floor level of the filter house to prevent filters getting water-logged.

● If requested by the Purchaser, filter house(s) floors shall be solid plate steel to prevent water droplet carryover to lower floors.

● If requested by the Purchaser, filter holding frames, where applicable, shall be normal to the direction of flow and terminate close to the outer walls of the filter house.

The use of W-shaped filter frames in the first stage of the filter house should not be provided as they may create non-even loading of the filter media.

The Contractor shall provide access to the filter house from a mobile platform to facilitate lifting of filter elements to and from the filter house. Where this is not possible, an efficient permanent system shall be provided to facilitate lifting of filter elements to and from the filter house. Where applicable, the design of any hoist or lift shall comply with all regulations, legislation and codes and take into account manual handling activities, access/egress and speed of lift to aid filter replacement. The Contractor shall provide, at the contract stage, a lifting plan to describe the safe method of lifting filters to the various platforms on the filter house. The plan shall show the basket/cage or similar device used to support the filters during the lift. The features, where applicable, for lifting and handling the filter element shall be documented in accordance with the document data sheet.

Drainage shall be provided for any storm water to be drained prior to it reaching the first stage of filtration. Sufficient amount of floor drains for the site conditions shall be provided in each filter house on the clean and dirty air sides of each set of filter frames and routed to a single collection point. Clean side drains shall include means to ensure the filter cannot be bypassed, and if icing is a possibility means shall be provided to prevent it.

Access stairways, platforms and walkways shall be in accordance ISO 14122-2:2001, 4.2.2. Each filter house shall be fitted with access doors sized for access of personnel and replacement filters together with all maintenance equipment required for changing filters. They shall be lockable, be able to be latched when in the open position and be able to be opened from the inside while locked.

The access platform outside the filter house doors requires a minimum area of 1,5 m x 1,5 m to allow safe handling of the filters by several persons.

All installed equipment that requires operational or routine maintenance activities to take place shall be accessible at all times by either fixed permanent access platforms or from ground level.

20.4 Water removal systems

The filter house shall, where required by site conditions, include a system for moisture separation that shall minimize the water content reaching the final stage filters. Where the Purchaser's site is coastal, the Contractor shall consider the water droplets from marine fogs in addition to site rainfall in designing the water removal system.

Where specific filter features are provided for water removal due to the environment at the filter location, the water removal efficiency shall be quoted at the tender stage on the information data sheet based on the selected filter type recommended by the Contractor (see 20.1).

Where the inlet face of the filter house utilizes vane-based water removal techniques, appropriate features shall be provided to achieve adequate drainage and prevent re-entrainment.

The water removal features and drainage system shall be documented in accordance with the document data sheet.

20.5 Inlet cooling systems

Inlet cooling systems shall typically recover lost capacity at high ambient temperature but may require large amounts of water for evaporative cooling. The Contractor shall specify requirements and water quality for cooling purposes on the information data sheet.

Chillers shall include full drainage capability with means to ensure the filter cannot be bypassed, and if icing is a possibility means shall be provided to prevent it. Where the potential for icing exists, appropriate measures shall be taken.

● If requested by the Purchaser, the Contractor shall supply the selected inlet cooling system option selected by the Purchaser.

The Contractor shall document any maintenance requirement, risks and operating restrictions to the gas turbines resulting from continuous use of evaporative/fogging systems, and, specifically, any existing field service instructions that relate to the use of inlet cooling systems, in accordance with the document data sheet. Potential problems include blade erosion, coating loss (that can result in high cycle fatigue cracking), blade tip rubs and inlet duct and liner corrosion.

20.6 Inlet ducts and silencer

The layout of the inlet filter house, inlet ducting, transition pieces, inlet silencer, flexible joints (where applicable) and the support structure shall be defined in accordance with the document data sheet.

Inlet ducts and silencer arrangements shall be adequately supported or utilize a flexible joint to ensure excessive loads are not placed onto the gas turbine inlet flanges. Design shall allow for ample thermal growth due to environmental conditions. The gas turbine manufacturer shall define the permissible loadings at the gas turbine compressor inlet interface. If the duct design is provided by a third party (contracted by the Purchaser), the duct design data shall be supplied to the Contractor who shall review the design for acceptable flow path conditions.

Inlet ducting shall have the minimum number of direction changes to minimize pressures losses. Where direction changes are unavoidable, turning vanes or other means to ensure even flow distribution and minimize inlet losses should be used. The turning vanes and supports shall be rigid enough to avoid resonance with a natural frequency outside of any exciting frequency and shall be continuously seam welded.

Method of access (panel, door, removal of filter elements) to enable final cleaning and future inspection of the inlet ducting shall be detailed by the Contractor in accordance with the document data sheet. Fasteners to be used on access features shall not increase the risk of ingestion.

Where necessary to avoid unacceptable noise, break out levels from the inlet ducting, transition pieces or silencer peripheral surfaces shall be externally or internally treated to attenuate noise breakout to an acceptable level.

Where an internal acoustic lining is used on ducting, internal surfaces of the silencer and silencer baffles, the lining shall be retained by internal perforated sheeting with an open area of typically 35 %. A suitable cloth or wire mesh shall be used between the acoustic infill and perforated sheet to prevent loss of material by vibration or air movement plucking effects. The weave of the retaining cloth or mesh shall be carefully selected to ensure attenuation performance is not degraded while preventing the passage of infill that can cause damage to the turbine. The duct and perforated sheeting supports shall be designed to minimize vibration effects on the acoustic infill and the air velocity profile within the duct shall be controlled to limit plucking effects. The infill material selected and the fixing features employed shall be such as to prevent the infill sagging/sinking downwards and reducing its effectiveness.

Where the passage of infill particles may cause damage to the turbine, a trash screen with a suitable mesh size to prevent passage of particles shall be supplied at the inlet to the turbine compressor. Where a trash screen is not offered, the Contractor shall provide, in accordance with the document data sheet, significant long-term service experience to demonstrate the integrity of acoustic lining systems. Where no significant experience exists, the Contractor shall provide a detailed design assessment, in accordance with the document data sheet, outlining the failure mechanisms considered (e.g. flow induced resonance, mechanical resonance, corrosion and maintenance related damage) and the design, analysis and test mitigation work carried out.

First of type (new) designs shall be reviewed to ensure that air flow pattern is acceptable and damaging vortices are eliminated.

Suitable drains shall be provided at low points for the drainage of water to prevent water that may have collected from water wash or other processes from entering the gas turbine.

20.7 Resonance of ducts, silencer or turning baffles

Ducting and internal components shall be designed such that they are not subject to resonance excited by flow or mechanical sources. Resonance increases the risk of system cracking and release of material to the gas turbine.

20.8 Materials, fixings cladding and sealing

The inlet ducts shall be constructed such as to minimize mechanical fixings that are exposed in the inlet duct. Where this is unavoidable, anti-vibration washers, locking tabs or tack welds shall be used to secure nuts. Where brackets are installed in the inlet duct they shall be of welded construction.

Where a non-welded joint is used between clean air and dirty air, a gasketed joint shall be provided. The gasket material shall be reinforced insertion rubber or similar material with suitable tear, blow-out, leakage and weather resistance. The low compression set and high resilience gasket material shall be compressed sufficiently to provide a durable sealing function without the need for additional maintenance. When assembled, the compressed gasket shall not protrude from the flange internal perimeter or otherwise impede air flow.

● The Purchaser shall select on the options data sheet the option required for different materials for the inlet system for the following elements:

— filter house outer panels;

— filter house and ducting support structure;

— filter element support frames;

— rain or snow hood panel and frame;

— trash or insect screen and frame;

— silencer panel and frame;

— ducting panels.

For C4 and C5 (I or M) environments defined by ISO 12944-2:1998, materials shall be selected that are resistant to corrosion from saliferous conditions that could create the potential for the ingestion of components of corrosion. Where such materials are not selected by the Purchaser, the Contractor shall advise the applicable change in material required in the Contractor's response column provided in the options data sheet. Galvanized/Zinc plated materials shall not be used in environments where saliferous conditions could result in surface oxidization leading to the ingestion of components of corrosion into the gas turbine gas path leading to the potential for stress accelerated grain boundary oxidation (SAGBO).

20.9 Isolation flaps and roller shutters

In some cases, a flap or roller shutter system is used to isolate the inlet following shutdown to aid dehumidification of the gas turbine and prevent the large draft through the gas turbine during inspections.

● If requested by the Purchaser, the Contractor shall provide a means of protecting the gas turbine rotor from wind milling during shutdown periods (where conditions for wind milling may exist) by the installation of an inlet shutter (or some other device for closing the inlet duct and preventing air flow). The isolation system type shall be identified on the options data sheet and the system details documented in accordance with the document data sheet.

● If requested by the Purchaser, a permanently installed dehumidifier shall be supplied together with a means of closing the inlet duct and preventing air flow (such as a shutter) to prevent long-term corrosion except where the environment can be shown to have low humidity throughout the year. Where this requirement is selected by the Purchaser, the Contractor shall provide (at the contract stage) verification of the design integrity of the inlet shutter (if the design is new) or fleet experience to establish the design as proven. The isolation device shall be provided with protection to ensure the gas turbine cannot start with the isolation device closed or shutdown the machine in the event of inadvertent closure. The system details shall be documented in accordance with the document data sheet.

20.10 Anti-icing

20.10.1 General

The operation of combustion gas turbines in cold climates can present a unique problem: inlet icing. Icing can plug static inlet filtration systems. Icing can also rapidly increase the pressure drop across trash screens and other inlet components, leading to performance loss and possible damage to ducting from negative differential pressure. In extreme cases, ice can build up on bellmouths, risking foreign object damage and compressor surge. Anti-icing systems are designed to inhibit ice formation on inlet components in order to protect the gas turbine from these hazards.

NOTE Anti-icing is typically required when the air temperature is between −5 °C to 5 °C and the relative humidity is above 70 %. Icing on the filter is also influenced by the velocity of air.

Where applicable, the Contractor shall specify and document, in accordance with the document data sheet, the need for an anti-icing system based upon their experience and the Purchaser’s site conditions and provide their recommended system based on the various methods covered in 20.10.2 to 20.10.6. In all cases, the Contractor shall provide evidence to demonstrate that the offered system shall prevent filter house and bellmouth anti-icing.

● If requested by Purchaser, the Contractor shall supply the anti-ice system selected on the options data sheet from the options listed in 20.10.2 to 20.10.6.

The Contractor shall provide documentation covering the selected anti-icing system including, but not limited to, the impact on performance, pressure drop through method used, instrumentation, sequence and timing of controls, heat load and media/utility requirements.

20.10.2 Compressor bleed anti-icing heating (static filter)

A compressor bleed anti-icing system increases inlet temperature without affecting absolute humidity by using a portion of the compressor discharge air for this purpose.

The Contractor shall confirm that the noise levels with the anti-icing on (at full flow) comply with site requirements on the information data sheet.

20.10.3 Electric infrared heating (static filter)

Infrared radiation comprises a bank of radiant elements, upstream of the inlet filters, that permits more rapidly available heating and is more energy-efficient than a compressor bleed system. Safety measures against fire risk shall be in accordance with 20.10.7.

20.10.4 Inlet coils steam or hot water heating

An inlet heat exchanger upstream of the inlet filters, comprising coils, is used where available steam or hot water is run through the coils and heats the incoming cold air to avoid freezing of the filter media. Appropriate measures shall be taken to avoid freezing of any water when the system is not operating.

20.10.5 Electrical resistance heating

Electric resistance heating upstream of filters may be used. This type of heating typically consists of banks of tubular sheathed heating elements, which may incorporate fins, suitably located and supported such that the velocity of the air stream does not impose vibrations in the elements.

20.10.6 Pulse clean filters

Pulse filters provide ice or dust removal on the face of the filter. These systems do not provide protection from ice formation (due to lower pressure) at the bellmouth so an additional system may be required to provide heat to the bellmouth. Pulse clean filters may not be suitable for sites with high seasonal humidity so the Contractor shall provide test evidence of the suitability of this system for the Purchaser's site.

20.10.7 Inlet heating fire protection and access limitations

Hot heater surfaces, radiant heat sources and high temperature bleed air shall be appropriately located/distributed such that the potential for igniting filter media and any other combustible materials is eliminated. The Contractor shall document, in accordance with the document data sheet, the measures taken for reduction of risk from fire. The operating manual shall advise any access limitations to the area while heaters are in operation and, where applicable, suitable means shall be implemented to prevent/control access prior to the heating being operated.

21 Exhaust system

21.1 General

The design and layout of the exhaust system depends on the application of the gas turbine for simple cycle or combined cycle operation. For simple cycle operation, it guides the exhaust flow of the gas turbine from the exhaust outlet interface via an expansion joint, diffuser and exhaust ducting to the atmosphere. For a combined cycle application, it guides the exhaust flow of the gas turbine from the exhaust outlet interface via an expansion joint, diffuser and exhaust ducting to a heat recovery system.

In the case of a combined cycle application, the exhaust system connects the gas turbine exhaust with the heat recovery steam generator (HRSG) for the production of steam used in a steam turbine or other heat/steam extraction purposes. Where a HRSG is installed, an optional diverter damper may be utilized to allow the exhaust to bypass the HRSG and direct the power generation package exhaust flow directly into the atmosphere in case the HRSG is out of operation or being serviced.

The exhaust system of a power generation package typically consists of at least the following key equipment:

— expansion joints;

— equalizing and transition ducts to guide the flow;

— exhaust silencer;

— elbow duct and exhaust stack;

— turning vanes and flow guides;

— supporting frame duct(s), silencer(s) and stack with all fixations, support elements and anchorage including embedded parts;

— instrumentation and control equipment.

The Purchaser shall advise, on the information data sheet, whether the power generation package shall operate as a simple cycle installation or as a combined cycle installation in conjunction with a HRSG (see Clause 25).

● If requested by the Purchaser, a simple cycle exhaust stack configuration shall be provided including an expansion joint, diffuser, silencer, ducting, support structure and including, where applicable, exhaust elbow duct, flow guides and turning vanes in accordance with the requirements defined in the applicable subclauses of Clause 21. The orientation of the exhaust outlet required shall be defined.

● If requested by the Purchaser, a combined cycle exhaust outlet including an expansion joint, diffuser ducting and support structure and including, where applicable, exhaust elbow duct, flow guides and turning vanes in accordance with the requirements defined in the applicable subclauses of Clause 21. The orientation of the exhaust outlet required shall be defined.

● If requested by the Purchaser, a combined cycle exhaust configuration with bypass exhaust stack shall be provided including an expansion joint, diffuser, diverter damper, bypass stack silencer ducting and support structure and including, where applicable, exhaust elbow duct, flow guides and turning vanes in accordance with the requirements defined in the applicable subclauses of Clause 21. The orientation of the exhaust outlet required shall be defined.

● If requested by the Purchaser, aircraft warning lights shall be provided on the exhaust(s).

● If requested by the Purchaser, sampling points for emission measurements shall be provided on the exhaust system. Depending on the location of the sample point, there shall be platforms and ladders for its access.

● If requested by the Purchaser, lightning conductors shall be provided on the exhaust(s).

21.2 Interface between gas turbine and exhaust system

The Contractor shall define the flow conditions with mass flow, pressure, temperature and diameter at the interface between the gas turbine package and the exhaust gas system as defined in the information data sheet. A general arrangement drawing (see Clause 35) shall include dimension details of the interface as far as required to connect the gas turbine exhaust outlet to the exhaust system.

For the decoupling of mechanical reaction forces, the transmission of vibrations and to allow an appropriate thermal expansion, the gas turbine exhaust diffuser shall be connected with the exhaust gas systems via an expansion joint. The maximum axial, radial and angular thermal expansion and the maximum allowable forces at the interface shall be defined on the information data sheet to allow a proper design of the expansion joint. The design of the expansion joint shall take noise requirements into account (see 7.3) and the maximum allowable equipment external surface temperature according to applicable health and safety requirements defined by the Purchaser on the information data sheet.

The design of the expansion joint shall take into account imposed shear and bending moment loads. Guards shall be provided, if applicable, to prevent damage. Internal plates or other means to prevent turbulence or deposition of dust and liquids in the joints shall be incorporated, where applicable.

If the expansion joint embodies a local risk of fuel accumulation, it shall be equipped with appropriate drain equipment at the lowest point.

21.3 Design requirements

Where required, turning vanes, flow guides or vortex-shedding devices shall be installed in the exhaust gas system to avoid excessive pressure losses, flow disturbance or noise emissions. The pressure loss of the exhaust system is defined on the information data sheet. In case of a combined cycle with a HRSG, the exhaust duct shall be defined with a sufficient distance between power generation package exhaust and any equipment arranged downstream such as silencers or the HRSG to ensure the correct functionality and mechanical loading of the equipment.

Any thermal expansion loads exerted on the gas turbine interface shall not exceed acceptable limits.

Where applicable, sliding supports not requiring lubrication shall be provided to allow free expansion of the duct work.

Materials used for the exhaust system shall be suitable for the flow and temperature conditions.

Access to the exhaust gas system shall be provided by a manhole if the channel size is large enough for such an access.

The maximum exhaust temperature at the gas turbine exhaust diffuser output and the conditions at which it occurs (e.g. MCR or, if applicable, peak load) shall be specified.

21.4 Mechanical requirements

The power generation package exhaust system is subject to high mechanical load and wear as the result of the fast transient temperature cycles during start-up and shutdown and the high temperature level it is exposed to during operation. This may result in a significant degree of wear and cracking, which can reduce the lifetime of the exhaust gas system significantly.

Therefore, the design shall be based on proven design solutions to avoid extensive wear, fatigue or cracking or other mechanical damage during operation. Furthermore, high temperature corrosion shall be avoided by an appropriate selection of suitable materials for the exhaust system at high temperature service. The life of the exhaust system shall meet the lifetime and operation cycles requirements defined in Clause 34.

The supports of the exhaust gas system shall be designed to avoid excessive heat impact on the concrete foundation.

21.5 Insulation

The exhaust gas system shall be insulated inside or outside of the ducts to keep the maximum surface temperature below the required allowable maximum limits specified in ISO 21789:2009, 5.8.1.1 and meet the noise requirements in 7.3. Personal protection insulation shall be provided to comply with applicable health and safety requirements and achieve the maximum allowable external surface temperature defined on the information data sheet for 21.2.

The insulation shall be adequately protected from mechanical, water or weather damage, or from absorbing oil, by the provision of sealants or cladding.

The duct insulation material shall be free of any asbestos. It shall be chemically inert and remain so in the event of being saturated with water. Where insulation material contains leachable chlorides, hot surface barriers should be considered.

The design shall allow removal of the insulation without damages at measurement devices and for accessing manholes requiring frequent maintenance access.

21.6 Noise requirements and silencers

The exhaust system typically includes one or more silencers to meet noise emission requirements, which can be arranged either in the horizontal or vertical part of the exhaust gas system. In addition, acoustic insulation is typically required before the silencer and can be applied to the inside or outside of the exhaust duct. There is typically one insulation system meeting thermal insulation needs as well as acoustic insulation requirements. The Contractor shall document the thermal insulation and acoustic silencing features of their exhaust in accordance with the document data sheet.

Low frequency noise generated in the gas turbine or induced by the exhaust flow shall not lead to mechanical damage in the exhaust gas system. In general, the flow path shall be designed in a way to reduce flow-induced noise.

For noise emissions at the exhaust stack and near field noise at the exhaust gas system ducting, refer to 7.3.

21.7 Safety requirements

Where the potential exists for the exhaust gas system to contain an explosive atmosphere, or gases or vapours that can create an explosive atmosphere, the exhaust gas system shall be purged before gas turbine start-up.

Where liquid fuel is used, suitable drain points shall be incorporated to drain off unburnt fuel from the exhaust gas system. Special care shall be taken for localized low points such as expansion joints or similar.

Starting of the gas turbine package without a full exhaust system purge immediately prior to start-up can be undertaken, subject to risk assessment in accordance with ISO 21789:2009, 5.12.4. NFPA 85:2015, 8.8.4.6 for gaseous fuels and NFPA 85:2015, 8.8.4.7 for liquid fuels, as applicable, provide a method of achieving adequate risk reduction. Gas vents shall be to atmospheric pressure. These procedures shall ensure that an explosive atmosphere does not exist within the exhaust system prior to starting the gas turbine package. The Contractor shall advise, on the information data sheet, which of the above standards applies to their purge system.

The Contractor shall advise the maximum acceptable system back pressure at the termination point on the information data sheet. To protect the gas turbine from excessive back pressure, fault monitoring shall be provided by pressure monitoring or, where applicable, by damper position monitoring to prevent adverse impact to the gas turbine.

The Purchaser shall identify, in accordance with the document data sheet, any additional purging regulations and legislation. Where applicable, HRSG flow requirements and/or specific customer requirements not specified in the above paragraphs of 21.7 shall also be documented in accordance with the data sheet.

See Clause 24 for any additional purging where a HRSG is utilized.

21.8 Diverter damper

In the case of a combined cycle application, an exhaust gas diverter damper might be required to either guide the flow via a HRSG to an exhaust stack during combined cycle operation or bypass the HRSG and guide the flow directly via the power generation package exhaust system to the exhaust stack during simple cycle operation.

If selected as required (see 21.1), the scope of the exhaust gas diverter damper package shall consist of all required mechanical, electrical, hydraulic and instrumentation equipment to operate the diverter damper. The diverter damper seal type (mechanical, buffer air) shall be defined and external air requirements, where applicable, detailed by the Contractor on the information data sheet.

The closing speed of the damper shall be aligned with operational requirements of the gas turbine to avoid any unintended exhaust gas flow situation and is defined on the information data sheet. The typically high inertia of masses for movement of the diverter needs to be considered for a safe and reliable operation of the exhaust gas system.

● If requested by the Purchaser, a locking device to lock the diverter damper in the HRSG closed position shall be delivered; it shall withstand at least 150 % of the maximum possible actuator torque.

If exhaust dampers are fitted, controls shall be provided to detect uncontrolled damper closure and to shutdown the gas turbine before an overpressure condition can arise.

21.9 Exhaust stack

If selected as required (see 21.1), the exhaust stack shall be designed in a way that all emissions are sufficiently dispersed to avoid any danger to health and safety and to meet noise requirements. The elevation of the exhaust gas stack mouth shall be sufficiently higher than the air intake system inlet and is typically a matter for regional, national or local regulations.

The flow path channel dimensions of the exhaust gas stack shall be large enough to avoid any additional excessive flow induced low frequency noise.

Where bolted connections, expansions joints, instrumentation, warning lights or other equipment requiring periodic maintenance are installed at the exhaust gas stack, access to such equipment shall be provided.

● If requested by the Purchaser, weather protection features shall be supplied at the stack mouth to protect the stack inside from rain. Where installed, flaps shall open independently in case of an overpressure situation.

22 Civil design and foundation requirements

22.1 General

The civil works shall be the responsibility of the Purchaser and shall be designed for a life that is consistent with the life of the power generation package. Recommendations are listed below for guidance.

— 20 years for reinforced concrete structures.

— 20 years for main structural elements.

— 20 years for process elements.

— 20 years for secondary structural elements and cladding.

— 10 years for temporary facilities.

22.2 Basis of design

22.2.1 General

The Contractor shall define the following types of loads, where applicable, for the Contractor's equipment imposed on the foundations, taking into account the applicable condition at the site defined by the Purchaser, including the following:

— dead;

— imposed;

— wind loads;

— seismic;

— thermal;

— electric overhead travelling cranes;

— other power plant loads including those imposed during erection, installation and maintenance.

22.2.2 Allowable bearing capacity

The allowable bearing capacity and other soil parameters to be used in the design of the civil works for all structures shall be appropriate for the long-term serviceability of that structure.

22.2.3 Foundations, settlements and defections

The Contractor shall provide the information to the Purchaser required for the design and construction of foundations for the gas turbine package in accordance with the document data sheet. These shall include foundation loads, holding down and jacking point locations, required pipe and wiring trenches, operational temperature profiles, recommended foundation interface hardware designs, dynamic design criteria and recommended deflection limitations, where applicable.

The construction of the foundations shall be such that adequate strength, long-term stability and suitable dynamic properties are achieved.

Foundation deflections may arise due to long-term foundation differential settlement. The Contractor shall provide, in accordance with the document data sheet, allowable limits for foundation differential settlement for those installations with separate foundations for the gas turbine package and associated driven/connected units. This allowance should be consistent with the type of foundation construction (e.g. piled versus soil supported) and site soil type.

Settlements shall not exceed the recommendations of EN 1997-1.

22.2.4 Levelling datum(s)

● If requested by the Purchaser, the Contractor should provide recommendations for foundation settlement benchmarks for the gas turbine package and associated driven/connected units in accordance with the document data sheet. The benchmarks shall be either located on the foundations or located on the equipment bases such that any relative foundation settlement, over time, can be measured and corrected.

If located on the foundations, it is the foundation designer's responsibility to determine exact locations for benchmarks based upon information provided by the Contractor. Protective covers shall be provided to prevent benchmarks from being damaged or upset.

If located on the equipment bases, it is the Contractor's responsibility to determine exact locations for benchmarks based on the Contractor's knowledge of the equipment. Benchmarks shall be such that accidental movement cannot occur or suitable protective covers shall be provided to prevent benchmarks from being damaged or upset.

23 Generator design interface requirements

23.1 Electrical fault torque

The gas turbine package shall be designed to withstand without failure a generator short circuit as defined by IEC 60034-3: 2010, 4.16 while operating at rated load.

Where the generator is not supplied by the Contractor, the Purchaser shall supply all necessary electrical system information (including an over-torque versus time curve) to the Contractor to conduct a fault torque analysis in accordance with the document data sheet. The Purchaser shall advise whether the maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from a three-phase short circuit as specified by IEC 60034-3:2010, 4.16 on the information data sheet.

"Without failure" means that the machine shall not suffer damage that causes it to trip out of service. It may be necessary to check for possible shaft balance changes and deformation of the coupling bolts and couplings.

23.2 Matching of the generator to gas turbine

The Purchaser should choose a generator that fulfils the requirements of IEC 60034-3:2010 and that matches the gas turbine, including the required performance for the gas turbine, by techniques such as peak firing, inlet cooling, water and steam injection. It should also match the full variation in site conditions. Where the gas turbine is to run at an extremely low ambient temperatures, care shall be taken to ensure that the generator's capability shall match the maximum turbine output as specified by IEC 60034-3:2010 and IEEE C50.13 or the gas turbine control should limit the output at these conditions to match the generator's capability.

23.3 Generator overspeed

The generator shall fulfil the overspeed test requirements as specified by IEC 60034-3:2010. The Contractor shall advise the Purchaser of the overspeed capability required on the information data sheet for equipment connected to the main drive shaft in the event of a gas turbine overspeed.

23.4 Starting device

Where, for starting, the gas turbine is rotated by the generator using a static frequency convertor or similar and the starting device is not supplied by the Contractor, the Contractor shall provide the Purchaser with the following data in accordance with the document data sheet:

— gas turbine core rotor inertia;

— breakaway torque;

— barring speed;

— purge speed;

— curve of speed versus time during start-up;

— self-sustaining speed;

— speed at which the starting assistance may be progressively reduced;

— speed at which starting assistance may be removed.

Protection shall be provided to detect loss of generator excitation and trip the unit. The protection shall prevent abnormal operation such as pole slipping of a synchronized machine and the resulting rapid gas turbine core acceleration and decelerations and possible torsional excitations.

● If requested by the Purchaser, the Contractor shall supply the necessary equipment to use the generator as the starting device.

24 Heat recovery steam generation design interface

● If requested by the Purchaser on the options data sheet that the gas turbine package is to be used in conjunction with a HRSG, the following requirements shall be complied with and the associated data supplied.

The HRSG inlet ducting and supports shall be designed to prevent vibration and to ensure the following:

— the loads exerted on the turbine do not exceed acceptable limits for the turbine or change because of thermal effects;

— free expansion of the duct, and that sliding supports shall not require any lubrication;

— material for the ductwork, guide vanes and expansion joints shall be suitable for the flow and temperature conditions.

Expansion joints shall be designed as follows:

— such that their replacement is not required before a scheduled gas turbine major overhaul;

— such that no shear loads or excessive bending moments are imposed upon them;

— with guards, if required, to prevent external damage to the bellows, while allowing the free circulation of air;

— with internal plates or other means to prevent turbulence or deposition of dust and liquids in the joints;

— so that their position minimizes lateral movements at the joints.

The HRSG supplier shall ensure that the HRSG does not constrain the operation of the gas turbine and will provide the initial back pressure estimate. With regards to the matching of gas flows and temperatures, data sheets shall be provided by the Contractor detailing the exhaust characteristics for the range of project fuels and ambient conditions. As a minimum, the Contractor shall provide exhaust data, as detailed on the information data sheet, to the Purchaser at MCR and MEL for the following conditions:

— site reference conditions, as described in Clause 5;

— maximum flow conditions for the range of site ambient conditions specified by the Purchaser in 6.1.

● If requested by the Purchaser, additional part load and transient conditions as defined above shall be documented on the information data sheet at the loads specified by the Purchaser.

The Purchaser shall confirm the reference exhaust system back pressure at reference flow and temperature at the terminal point (gas turbine exit diffuser). These values will be considered for the gas turbine performance calculations.

The Purchaser shall identify any additional purging regulations and legislation and the applicable HRSG flow requirements and/or customer specific requirements above that required in accordance with 21.7 in accordance with the document data sheet.

Documentation shall be provided to identify the mechanical interfaces between the gas turbine exhaust system and the HRSG and any shared support requirements in accordance with the document data sheet.

25 Combined cycle applications

25.1 General

The principle of a gas turbine combined cycle is to extract heat energy from the gas turbine exhaust. A combined cycle gas turbine arrangement typically consists of a HRSG used to provide steam for a steam turbine.

25.2 Gas turbines in combined cycle applications

If the gas turbine is operated in a combined cycle application, either in a multi- or single-shaft arrangement, additional safety and operational requirements compared to a simple cycle gas turbine application need to be considered and managed by the Purchaser.

In case of a direct or indirect (via a heat exchanger) use of steam from a combined cycle HRSG, for gas turbine cooling or power augmentation, operational and safety requirements need to be considered in the operation and protection concept and defined in accordance with the document data sheet. This shall be the responsibility of the Contractor. The requirements for the supply of steam shall be defined in the documentation as described in 6.3. Gas turbine start-up interlocks or restrictions during run-up to idle or full load operation may appear, as well as restrictions for part load operation of the gas turbine.

In addition, the Purchaser shall manage any requirements for safe operation of the steam turbine following the intended operation concept. These operational requirements shall include the important physical or functional relationship between the gas turbine, the HRSG and the steam turbine. Specific aspects in this regard need to be highlighted in the operation and maintenance manuals and documented in accordance with the document data sheet.

The required exchange of signals and commands between the different components shall be documented, in accordance with the document data sheet, to ensure a safe and reliable operation of the gas turbine.

25.3 Single-shaft arrangements start restrictions

25.3.1 General

Where a steam turbine is connected to the gas turbine with a solid shaft (no clutch fitted) as a single-shaft combined cycle unit, the Purchaser shall define on the document data sheet any start restrictions that apply from the steam turbine. The following known issues shall be addressed.

— Pressure reheat combined cycle gas power generation package in a single-shaft configuration may require cooling steam to the low pressure (LP) and intermediate pressure (IP) turbines during start-up and particularly at full speed due to windage heating effects.

— Extensive barring or operation at higher speeds such as purging may also result in windage heating of the last stage blades of the LP steam turbine.

— Start of a hot steam turbine may be of concern if the high pressure (HP) steam temperature from the HRSG has been allowed to drop, as it shall cause rapid chilling.

Gas turbine single-shaft arrangements consist of a gas turbine, a generator and a steam turbine with a common shaft. The arrangement of the different components is typically required in the sequence gas turbine–generator–steam turbine or gas turbine–steam turbine–generator. The components on the rotor are either connected by a rigid coupling or a clutch. The Purchaser shall define the shaft configuration for the single-shaft power train, which should be agreed upon between the Purchaser and Contractor and documented on the document data sheet

The gas turbine and the steam turbine part of such a single-shaft power train shall allow hand barring rotation of each part of the rotor for maintenance purposes. In case of a rigid coupling, additional measures to allow such a hand barring shall be provided. If a combined lube or jacking oil system is used for the gas turbine, the generator and the steam turbine of a single-shaft power train, the systems shall allow a rotor barring of one part of the rotor train. The Purchaser shall advise the Contractor of the lube oil and jacking oil requirements to the steam turbine and generator on the document data sheet if a combined lube or jacking oil system is used.

25.3.2 Single-shaft rotor train – with clutch

In a gas turbine–generator–steam turbine configuration of a single-shaft arrangement, the gas turbine and the generator can operate whereas the steam turbine is disengaged by a clutch, typically an overrunning type of clutch.

In case of the use of a clutch, the operation, maintenance and protection concept shall ensure that shafts cannot turn unintentionally at standstill. For example, when the clutch is disengaged the rotation of the steam turbine shall not cause any rotation of the gas turbine and generator; alternatively, when the clutch is disengaged the rotation of the gas turbine and generator shall not cause rotation of the steam turbine.

25.3.3 Single-shaft rotor train – no clutch

Where a steam turbine is connected to the gas turbine as a single-shaft combined cycle unit (no clutch fitted), there shall be specific operational procedures to prevent overspeed testing damaging the steam turbine. It is possible for this type of shaft configuration for the gas turbine to drive the steam turbine to overspeed test speeds without suitable steam turbine thermal conditions first being achieved. The Contractor supplying such shaft configurations shall identify any risk condition with overspeed testing and provide clear guidance for overspeed test limitations in accordance with the document data sheet.

26 Control and instrumentation requirements

26.1 Control

26.1.1 General requirements

The gas turbine shall be provided with a control and instrumentation (C&I) system that provides for start-up of the gas turbine and its ancillary systems, stable operation through the duty cycle and shutdown by both manual and automatic methods. The C&I shall provide protection for the equipment via alarm and trip functions. Tripping devices shall cause immediate shutdown by means of fuel shut-off in accordance with ISO 21789:2009, 5.20.8. A governor shall be supplied which provides for steady-state speed regulation.

● If requested by the Purchaser, a specific application of the gas turbine package requires operation to be maintained in the event of an interruption of externally supplied AC power. The period of time for which continued operation shall be maintained shall be defined by the Purchaser on the information data sheet.

Where applicable, displays continuously available to the operator shall include a method of displaying the set points for each transducer available to the distributed control system (DCS) in a form that enables the measured value and the set points to be readily compared.

26.1.2 Architecture

26.1.2.1 General

The Contractor shall advise the actions performed by the control and safety devices in the event of control circuit failure in accordance with the document data sheet.

26.1.2.2 Simplex systems

If not otherwise specified by the Purchaser and the control system reliability figures can be shown to be better than the gas turbine and in line with the Purchaser's requirements, a simplex control system shall be considered acceptable. A simplex system shall employ adequate safeguards ("watchdogs") to monitor for processor hardware or software failure and take necessary executive action to force the outputs to a safe state or watchdog trip.

26.1.2.3 Fault tolerant systems – increased availability

● If requested by the Purchaser that it is vitally important that unscheduled shutdowns are kept to a minimum, the control systems, power supplies, gas turbine instruments and end devices shall be provided with additional hardware and voting logic and on-line change-out of the offending control component or instrument where practical.

26.1.3 Human machine interfacing (HMI)

The control system shall provide the operator with a computer/monitor based display system, providing equipment mimics, displays, performance information, shaft speeds, gas path temperatures, hours run, number of starts, trend information, and alarm and shutdown logs. Logs shall be capable of containing sufficient information as to allow detailed analysis of the cause of the alarm or shutdown. The operator shall be able to view the status of any alarm, trip or permissive signals without having to attempt to initiate the equipment action (see 11.7 for location of HMI).

● If requested by the Purchaser, the control system shall be supplied with fault diagnostic capability to help identify C&I component faults.

26.1.4 Alarm and annunciation

26.1.4.1 Fault shutdown

The control system shall employ a first fault requiring a reset before starting, and fault shutdown sequence, the output of which shall be displayed at the HMI monitor. The fault output annunciation shall not clear itself until manually reset.

● If requested by the Purchaser, the output shall also be displayed on a lamp box style annunciator.

26.1.4.2 Status information – fault warning

The control system HMI shall clearly indicate to the operator the status of the gas turbine during start-up, running and shutdown, and shall advise the operator when a command input is required to acknowledge a fault warning.

The control system HMI shall employ a flashing warning display to alert the operator of a fault. The output shall clearly indicate the sequence in which the faults occur. The fault output shall not clear itself until manually accepted and the fault level has returned to normal.

The control system HMI shall be provided with an audible alarm for warnings and shutdowns and outputs to drive a remote flashing light and the klaxon or another audible device when associated with a fire and gas function. If the alarm is acknowledged, the klaxon or other audible device shall be silenced, but the light shall remain lit as long as the alarm condition exists.

26.1.5 Starting

26.1.5.1 General

The gas turbine starting sequence, including pre-start requirements such as turning and purging, shall be fully automatic up to synchronization speed including starting in conjunction with combined cycle operation.

The Purchaser shall specify, and document on the document data sheet, where, due to the particular design of a combined cycle system, manual or semi-automatic start stages are required including any associated hold and release points.

The control system shall provide controlled acceleration to synchronization speed and appropriate warm-up time in order to reduce thermal strain effects, excessive mechanical stresses, or operation at critical speeds of any train component.

26.1.5.2 Start purge

The starting control system shall provide an automatic turbine, turbine exhaust and, if applicable, a gas turbine enclosure purge period before start-up to mitigate any risks associated with the auto-ignition of hydrocarbons during the start cycle in compliance with the requirements of ISO 21789:2009.

Where more than one gas turbine supplies a heat recovery system, precautions shall 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.

26.1.6 Sequence control

Automatic sequencing of the equipment shall be provided to a level compatible with the control requirements specified by the Purchaser to comply with the applicable operational and manning requirements.

● If requested by the Purchaser, the sequence steps shall be displayed at the controls interface.

Prior to handover, the Contractor shall demonstrate that the equipment is capable of being started, run and shutdown using normal procedures, without failures or the use of operator overrides and within the limit on number of manual operations. Throughout the defect liability period the performance of the sequence systems shall be monitored. Any reduction in performance or increase in failures shall be regarded as a defect requiring remedial work from the Contractor to re-establish the required level of performance or absence of failures.

● If requested by the Purchaser, the operator shall be provided with the ability to override certain sequence checks to prevent faulty signals interfering with operation. Overriding shall only be permitted on checks where the operator has secondary information that the applicable equipment is in the correct state. Proper protocol shall be provided for initiating an override to prevent casual or inadvertent initiation. Overrides set on one operation of the sequence shall be automatically cleared before the sequence is initiated again. Use of overrides shall not constitute normal operation.

The control system shall allow loading of the gas turbine manually or automatically up to the demanded power level. Manual operation requires the operator to raise the output to the desired set point. Automatic loading is when the output is automatically increased to the set point without manual intervention. Automatic loading may directly follow the starting sequence without any additional action of the operator. In any mode of loading, periods of dwell at specific outputs shall be introduced to meet warm-up requirements.

● If requested by the Purchaser, the control system shall allow for manual synchronization prior to loading, otherwise the control system will automatically perform synchronization.

26.1.7 Governing and limiting

26.1.7.1 Speed control

26.1.7.1.1 Governor transient performance

For single-shaft gas turbines the governor systems for generator drive shall prevent the gas turbine from reaching the gas turbine trip speed after an instantaneous loss of the maximum potential load. Where this cannot be achieved for twin shaft gas turbines the governor shall control the speed rise of the gas turbine and/or power turbine to a value which shall permit a restart without need for an inspection of the gas turbine after shedding of the maximum potential load. The Contractor shall advise the Purchaser of the maximum single step load that may be shed without tripping the gas turbine.

26.1.7.1.2 Speed control capability and stability

The speed governing system controlling the fuel rate for the gas turbine shall be capable of stable control of the speed of the gas turbine prior to synchronization of the generator with the grid frequency.

The system shall be considered stable when the generator is operated under sustained kilowatt load demand, provided that the magnitude of the sustained oscillations of turbine speed produced by the speed governing system and fuel control system does not exceed 0,4 % of the rated speed unless otherwise documented by the Purchaser on the document data sheet.

26.1.7.2 Temperature limiting and limit stability

The fuel control system shall include control parameters to prevent the gas turbine rated firing temperature (including ambient temperature compensation) being exceeded in conjunction with the speed control requirements including when the gas turbine generator is operating in parallel with other generators.

26.1.7.3 Module load control

● If requested by the Purchaser, and where applicable, the Contractor shall provide a module load control system that fully integrates the operation of the gas turbine(s) with other equipment specified, such as steam turbines and HRSGs, and documented in accordance with the document data sheet.

26.1.8 Unloading and shutdown

26.1.8.1 General

The control system shall allow unloading and normal shutdown by manual, semi-automatic or automatic means. Manual operation requires the operator to perform or initiate some pre-defined steps. Semi-automatic requires the operator to perform some functions, such as unloading manually, while other parts of the sequence are automatic.

The C&I system shall provide a sequence for unloading and shutdown, which would normally comprise the following:

— controlled unloading to the minimum load acceptable for protection while remaining synchronized;

— opening the circuit breaker;

— reduction to idling speed followed by a period of cooling under fired conditions, where applicable;

— fuel cut-off and shutdown of auxiliaries not required for turning;

— turning period, where applicable;

— shutdown of remaining auxiliaries, for example lubricating oil pumps, after gas turbine cool-down;

— reset to starting conditions.

The Contractor shall document in the operating manual the requirements for fired cooling and for turning/barring after shutdown and any limitations on subsequent start-up. Where turning/barring is provided it shall be automatically engaged/disengaged.

The Purchaser shall document any other conditions applicable to normal shutdown and the protection of equipment outside the scope of this International Standard on the document data sheet.

26.1.8.2 Emergency shutdown

Emergency shutdown may be manually initiated but shall occur automatically on operation of applicable gas turbine/process equipment protection devices. The emergency shutdown system shall comply with the requirements of ISO 21789:2009.

Depending upon the fault that initiated the shutdown, normal turning and shutdown sequences, as appropriate, may take place. An automatic restart shall not be possible without a manual reset.

The Contractor shall document in the operating manual any special conditions that have to be taken into account after an emergency shutdown before a restart is initiated.

● If requested by the Purchaser, additional emergency stop buttons shall be provided in specified locations and documented in accordance with the document data sheet.

26.1.8.3 Motoring

Where required for safety or machinery protection, means shall be provided, either on the gas turbine or on the generator, for the prevention of motoring of the rotors after shutdown.

● If requested by the Purchaser for machinery protection, means shall be provided, either on the gas turbine or on the generator, for the prevention of motoring of the rotors after shutdown.

26.1.9 Automation

26.1.9.1 Programmable systems

● If requested by the Purchaser, appropriate levels of access to the project specific software configuration shall be enabled using password control and shall be limited to the adjustment of settings/parameters within an acceptable range. Where possible, the Contractor shall select programmable equipment from the same manufacturer and equipment range, in order to limit the number of separate engineering facilities and software systems required. The manufacturer of programmable systems for key black box systems shall be stated in the tender.

● If requested by the Purchaser, the Contractor shall supply a specification and programme for the project to support the complete life cycle for all the software, firmware and configuration within the C&I supply. The specification and programme shall be supplied to the Purchaser in accordance with the requirements of the project programme, prior to any software being developed and shall include all the necessary steps relating to the provision of software, firmware and configuration for the project from design to commissioning and acceptance.

● If requested by the Purchaser, the Contractor shall prepare and implement a specification and programme for software management for all stages of their involvement with the project. The software management plan (SMP) shall be supplied to the Purchaser in accordance with the requirements of the project programme and in accordance with the document data sheet, prior to any software being developed.

● If requested by the Purchaser, all application software developed for the project shall be documented on the document data sheet so that an application engineer from the Contractor who has knowledge of the system but not the application can readily understand the application without reference to the original design team.

● If requested by the Purchaser, systems containing application software or configurations shall have capacity for expansion after commissioning in memory, disk space, readily available processing power and communications network capacity as specified by the Purchaser.

26.1.9.2 Modulating control

Modulating loops shall be provided such that automatic, flexible and effective control of all equipment is achieved across the full operating range. This shall include all major and minor control loops required to coordinate the overall response of the equipment and shall be designed in an integrated manner to provide an optimized balance between equipment flexibility, equipment efficiency and equipment life consumption.

The control loops shall be shown to be stable and not oscillate in any operating condition and at any load. This may require the control gains to be scheduled or control structures to adapt according to operating conditions or load. All controls shall actively ensure that appropriate operating constraints such as actuator position limits, motor current limits, temperature, pressure or flow limits, etc. are not exceeded. This shall be achieved through actively controlling to the constraint boundary. No such constraining action shall be held on any longer than is necessary.

All modulating loops shall be configured to maintain safe equipment conditions in the event of a failure within a loop, e.g. the loss of the measured value or loss of actuator feedback signal. Wherever it is possible and safe, loops shall maintain automatic control, even if this is in a degraded form. This may be achieved through the use of default values or simplified controller structures or algorithms to overcome failures.

Where degraded control is not possible or safe, the failure shall cause the tripping of the control loop to manual and/or the freezing of the actuator in its current position. An alarm to the operator shall be generated whenever a failure causes loop tripping or degraded control.

● If requested by the Purchaser, the Contractor shall provide control loop performance monitoring and diagnostic facilities for all control loops including, but not limited to, standard deviation data, duration of control loop operating in "Auto", and duration of control loop operating in constraint in accordance with the document data sheet.

26.2 Instrumentation and associated equipment

26.2.1 General

The gas turbine shall be adequately instrumented for ease of operation, maintenance and diagnosing of fault conditions.

26.2.2 Operability and diagnostics

Turbine C&I protection systems shall be designed as "fail-safe". Fail-safe for the purposes of this International Standard, when applied to a digital control system, shall be as follows.

a) **Binary instrument.** A binary input instrument (e.g. pressure switch) used to protect the gas turbine shall be preferably designed as "normally open" and is then closed when the gas turbine is running and re-opened again on fault. In some cases, the fail-safe design may imply to have binary instrument designed as "normally closed".

b) **Analogue instrument circuit.** An analogue instrument (e.g. thermocouple input) used to protect the gas turbine, shall be continuously monitored for open circuit and input value "out of range" detection. Either state shall cause the control system to take appropriate action, depending on the criticality of the parameter monitored and the level of redundancy.

c) **Binary control output circuit.** A digital output (e.g. relay output) shall be arranged to be "energized to run" and electrical power failure shall cause all binary outputs to move the process to a safe state.

d) **Analogue control output circuit.** The device being controlled shall be continuously monitored for position, directly or by inference; a position error shall cause the demand signal to be driven to its safe level.

e) ● **On-line testing of C&I protection devices.** If requested by the Purchaser, the Contractor shall advise the Purchaser where the level of redundancy on critical circuits and where continuous health monitoring of the instrument loops is provided, e.g. thermocouple open circuit and out of range detection.

26.2.3 Control equipment and instruments

Instrumentation shall be provided to monitor all pressures, temperatures and levels required for safe and reliable operation and diagnostics in accordance with the instrumentation data sheet.

● If requested by the Purchaser, applicable instruments shall have an integral digital display.

All instrumentation shall convert the measured parameter to an electrical signal with a resolution, accuracy and repeatability covering the needs of a safe and reliable operation.

Resistance temperature detector (RTD) sensors, in accordance with a relevant IEC standard, shall normally comply with Class B accuracy unless requirements justify a more accurate class.

Thermocouple (TC) temperature sensors, in accordance with a relevant IEC standard, shall normally comply with Class 2 accuracy, unless requirements justify a more accurate class.

RTDs/TCs installed by the Contractor shall normally be installed in thermowells to measure liquid temperatures.

Where RTDs/TCs are embedded in equipment such that replacement requires a major strip, a non-active duplicate device shall be implemented allowing rapid changeover of the connections external to the equipment.

All analogue instruments with associated transmitters supplied and installed by the Contractor shall output 4-20mA signals. Analogue process instruments should generally be "smart" devices and shall be supplied with suitable portable configuration tools.

All pressure instrumentation should preferably be fitted with a 3 port manifold for single pressure measurements or a 5 port manifold for differential pressure measurements to provide for *in situ* calibration.

● If requested by the Purchaser, primary isolation shall be fitted at the instrumentation line take-off point from the line being monitored.

Pressure devices which are allowed by the Contractor to be replaced at operation under full pressure at the fuel gas system shall be fitted with double block and vent isolation.

If switches are used for alarm and trip functions, switch settings shall not be adjustable from outside the housing. Pressure elements shall be compatible to the system fluids at all foreseeable operating conditions.

Control system binary inputs and output cards shall include light emitting diodes (LEDs) to show the status of individual equipment inputs and outputs. Where the hardware shall allow, the Contractor shall also label each input and output at the I/O card.

The control system shall avoid significant compressor rotating stall by the controlled operation of devices, such as variable guide vanes, variable stator blades, bleed valves and compressor discharge pressure as applicable.

● If requested by the Purchaser, the Contractor shall offer dual inlet guide vane and variable stator vane position monitoring for enhanced rotating stall protection.

26.2.4 Gauges

● If requested by the Purchaser, local pressure and temperature gauges shall be supplied. Gauges shall be heavy duty, corrosion resistant, suitably ranged, pressure protected and, where appropriate, suitably damped. The Purchaser shall document the function where the gauge is required on the document data sheet. The face of gauges shall have black printing on a white background.

26.2.5 Solenoid valves

The use of direct acting solenoid operated valves should preferably be limited to 25 mm (1 in) or smaller nominal size. If larger solenoid valve are used, the Purchaser shall be informed. All solenoid valves shall have at least Class F insulation or better, and shall have a continuous service rating. If larger valves are required, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves, etc.

26.2.6 Vibration monitoring and axial position equipment

Vibration probes/transducers and, where required for correct operation, axial position transducers shall cover the total drive train including gas turbine, steam turbine, generator and associated gearboxes and clutches.

Sufficient radial and/or seismic vibration probes/transducers shall be provided at each bearing and axial position transducers provided for each axially loaded shaft together with the associated mountings, signal conditioning units, cabling and monitoring equipment to facilitate safe operation of the equipment and provide appropriate warning and trip functions.

● If requested by the Purchaser, the Contractor shall provide pairs of radial shaft vibration probes located in accordance with ISO 10817-1 or API 670 at each hydrodynamic bearing where protection is provided by seismic vibration probes. Inactive spare probes shall be provided where probes cannot be replaced from the outside of the equipment.

● If requested by the Purchaser, the Contractor shall provide pairs of seismic vibration probes transducers located in accordance with ISO 2954 or API 670 at each bearing. Inactive spare transducers shall be provided where transducers cannot be replaced from the outside of the equipment.

● If requested by the Purchaser, the Contractor shall provide axial position transducers on each separate shaft in accordance with API 670. Inactive spare transducers shall be provided where transducers cannot be replaced from the outside of the equipment.

● If requested by the Purchaser, additional probes/transducers shall be provided at other key locations.

Once per revolution shaft phase reference probe markers for field balancing and analysis of vibrations shall be provided on each rotating shaft, line orientated consistently. For shaft lines which are not rigidly bolted together sufficient phase markers shall be provided to define the phase along the drive train. Markers shall be externally assessable unless permanent mounted probes are fitted.

All probes and transducers on a connected drive chain shall be orientated in a consistent direction.

Probes and transducers shall be capable of meeting the phase, amplitude and accuracies over the required frequency range applicable to their location and usage in accordance with ISO 10817-1 or ISO 2954 or API 670 or the Purchaser's specification. Instruments shall be located to minimize the potential for signal corruption. Where a gearbox utilizes transducers mounted on the gearbox bearings/casings, they shall have a frequency range of up to at least the fourth harmonic of the highest meshing frequency. The standards used shall be defined on the information data sheet.

Where seismic transducers are used applicable tracking filters to isolate specific compressor spool frequencies may be utilized.

● If requested by the Purchaser, specialized vibration transducers and monitors shall be supplied for use with rolling element bearings not covered by API 670. The Contractor shall provide details and specifications for the Purchaser to review in accordance with the document data sheet.

Vibration monitoring equipment shall comply with the requirements of API 670 and shall display in μm pk-pk for displacement, mm/s rms for velocity and m/s^2 rms for acceleration. Values shall be available for transfer to the data-acquisition system where specified (see 26.12). If normally used by the Contractor, S_{max} may be derived from pairs of orthogonal transducers at the measurement plane in place of pk-pk (see 18.2.2).

● If requested by the Purchaser, critical auxiliary rotating equipment shall be instrumented with vibration probes/transducers to allow adequate warning of likely failures and safeguard loss of generation. Key power plants with fast failure modes shall be monitored on-line while less important power plants with slower failure modes may use off-line systems. Transducers shall be fitted with suitable cabling and terminations for off-line systems where there is no safe access for portable transducers. Details shall be provided in accordance with the document data sheet.

26.2.7 Actuators

All actuators or associated valves shall be fitted with local indication of position and, where necessary to prevent a hazardous situation, shall freeze on absence of a command or loss of motive force or shall fail to a safe position. Following the loss of motive force, actuators shall retain all the necessary set-up positions without the need for integral batteries.

26.2.8 Trace heating

Where trace heating is required on control equipment and instrumentation, it shall be fitted in such a manner to enable easy removal of the applicable equipment for maintenance and shall not be capable of providing enough heat to damage the trace heated equipment under any process and fault conditions.

26.3 Cabling and control panel installation

26.3.1 General

● If requested by the Purchaser that they will be responsible for the installation of cables and associated controls equipment installation separate from the gas turbine package, the Contractor shall advise all instructions with respect to earthing cable segregation, electromagnetic compatibility and requirements with regard to dust, humidity, water, temperature and isolation from any source of vibration in accordance with the document data sheet.

The Purchaser shall specify the location and hazardous area classification (see IEC 60079-10-1) for the gas turbine package and for control equipment separate from the gas turbine package and the position of any additional operator stations and the degree of C&I monitoring required at each position in accordance with the document data sheet.

26.3.2 Cabling

Data and network cabling not within an enclosed panel/enclosure shall be mechanically protected or over armoured and supported by cable trays or other suitable means. Cables shall be suitably glanded at each item of equipment, at entries to terminal boxes, at gland plate and at the entry to cubicles. The design and installation of cabling, where applicable, shall allow removal where required to facilitate maintenance.

To minimize electrical interference, signal cabling shall be twisted in pairs with an overall screen. When a multi-pair cable carries signals that might cause interference between each other, each individual pair shall be screened.

The Contractor shall establish an instrumentation, cable, core and termination allocation and recording system. All cables, cores and terminals shall be clearly and unambiguously identifiable by a suitable and permanent tagging system or colour coding. All panels, terminal boxes and cabinets shall be clearly and unambiguously identifiable by a suitable and permanent marking system which identifies the equipment.

Panels, terminal boxes and cabinets for circuits where the voltage can exceed 50 V from earth shall be fitted with a warning sign and all the terminals where the voltage can exceed 50 V from earth shall be insulated or equipped with a core (end) sleeve.

Internal control panel wiring shall be to the Contractor's standard.

Where conduit is used, a length of flexible metal conduit, long enough to facilitate maintenance without removal of the conduit, shall be used at the interface to equipment, where necessary, for equipment maintenance and replacement. Potted glands shall be located such that disturbance is unnecessary during maintenance or equipment replacement.

All cable glands shall be certified for the hazardous area they are installed within. Low smoke, non-PVC sheathed cables shall be specified.

C&I cables within the gas turbine package shall be resistant to heat, moisture and abrasion, and oil-resistant where contact with oil can occur. Stranded connectors shall be used within the confines of the gas turbine package and in other areas subject to vibration. Where applicable, a high-temperature, thermoplastic sheath shall be provided for wire insulation protection, the sheath shall be oil-resistant where contact with oil can occur. Wiring shall be suitable for the environment temperatures.

● If requested by the Purchaser, intrinsically safe circuits shall use separate dedicated junction boxes, which shall be labelled as such, fitted with blue terminals and any exposed cables shall have a blue outer sheath. Multicore cables and other requirements for intrinsically safe circuits shall comply with IEC 60079-14:2013, Clause 16.

26.4 Electrical C&I equipment

26.4.1 General

Electrical C&I equipment shall comply with the requirements of IEC 60204-1:2009 and IEC 60204-11.

Instrumentation and associated equipment installed in an air-conditioned environment shall be protected to IEC 60529:2013 IP2X or NEMA equivalent.

Controls and instrumentation designed for outdoor installation and/or installed outdoors shall meet the requirements of IP65 as detailed in IEC 60529:2013 or NEMA equivalent.

Controls and instrumentation designed for indoor installation and/or installed indoors shall meet the requirements of IP54 as detailed in IEC 60529:2013 or NEMA equivalent.

● If requested by the Purchaser, terminal boxes shall be made of stainless steel.

Where required to prevent corrosion, control cabinets and other equipment containing electrical contacts, relays or instruments shall have dry air purge or anti-condensation heating.

C&I materials including insulation shall be corrosion resistant and non-hygroscopic in so far as is possible.

● If requested by the Purchaser for a tropical location, materials shall be suitably treated to protect against fungus attack, unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

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

26.4.2 Electrical supplies and other services

The Contractor shall define the external electrical supplies required for the operation of the C&I equipment.

The Contractor shall provide information on availability of battery supplies and alternative supplies.

The Contractor shall define requirements for the operation of the equipment for a specified period when one or more of the electrical supplies to it are disturbed or lost. The level of C&I system operation for the different degrees of disturbance may be specified.

The Contractor shall define the type and capacity of other external services for the operation of the equipment such as instrument air, pneumatic and hydraulic supplies, and the applicable response times when the supplies are interrupted (e.g. failure of compressors or pumps).

Documentation shall be provided in accordance with the document data sheet.

26.4.3 Spare termination

The Contractor shall normally allow for 10 % spare termination capacity and adequate space for additional I/O circuit boards where the type of usage/application may be subject to expansion (this requirement excludes special and black box applications where the design is such that expansion will not be required). This spare capacity may be used during the engineering of the project. The minimum amount of spare capacity remaining at the point of delivery shall be defined on the information data sheet by the Contractor.

26.5 Power supplies

26.5.1 General

The digital gas turbine package control system shall be powered by a DC supply. The HMI should be powered by uninterrupted AC power supply.

Other than for equipment requiring higher voltages, it is anticipated that C&I field equipment shall be powered at 24 V DC derived from the control system supply. Refer to Clause 27 for DC supplies to motors or other equipment where the power or voltage requirements exceed the supply available from the C&I DC supply.

● If requested by the Purchaser that they will be responsible for the supply of the uninterruptible power supply (UPS) systems, the Contractor shall advise on the voltage range and tolerance, with both static loading and inrush current conditions, in accordance with the document data sheet.

Where appropriate, the power supply(s) shall be categorized according to the significance of the apparatus they supply for safe operation, such as the following:

— electrical power supplies that are continuous (UPS, e.g. stand-by generators, floating battery systems and independent secondary supplies);

— electrical power supplies where the output can be subject to interruption for a short time;

— electrical power supplies where longer duration interruption can be tolerated.

It is essential that each C&I circuit is connected to a power supply system providing the correct level of integrity.

All protection devices shall have proven current/time characteristics. Control circuits shall be protected by a fuse or miniature circuit breaker (MCB) arranged so that each circuit can be isolated.

All actuators requiring to be operated during or following a unit trip shall be powered from UPS or battery-backed supplies unless they fail to a fail-safe position.

Where the AC supply is directly provided from the low voltage public distribution network, it shall be confirmed that the equipment associated with C&I shall work as intended with the voltage characteristics of the supply. The characteristics are given in EN 50160. Additional measures, e.g. surge protection, might be necessary at the installation.

26.5.2 Power supply sizing

● If requested by the Purchaser, the C&I power supply system shall be sized initially to have 25 % excess capacity to cater for design modifications. When first commissioned, the system ultimately shall be capable of supplying at least 110 % of the maximum design load in order to accommodate later minor additions.

The battery float and boost charging facility shall be sized to allow for the worst operating conditions, e.g. minimum and maximum battery room ambient temperatures coupled with the worst simultaneous loading conditions, while maintaining the supply within the required parameters.

A battery low alarm shall be available from the battery system to allow rectification action to be taken or shutdown of the equipment to prevent potential damage.

26.5.3 Intrinsically safe power supplies

Intrinsically safe control equipment may be loop-powered or may have a separate power supply. Where the power supply to the hazardous area equipment is separate to the signal loop, a barrier or isolator shall be installed in the power supply circuit to achieve conformity to the intrinsic safety design requirements in IEC 60079-11.

26.5.4 Battery systems

Battery systems for C&I and protection functions may be separate from any systems for supplying mechanical loads or may utilize the same battery system provided that sizing is such that loads for mechanical systems do not cause depletion of the battery charge such that the supply for C&I and electrical protection is reduced to a level that can cause a hazardous situation.

The C&I battery capacity shall be determined on the basis of the amount of energy needed for the following:

— safe shutdown and a seamless transfer to backup systems, where applicable;

— keeping the C&I system and safety functions operational for the longest period foreseeable that backup supplies will be unavailable to recharge the batteries;

— successfully restarting the unit when external supplies return; where the battery charge is insufficient to allow a subsequent shutdown a restart should be inhibited.

The Contractor shall specify the design life of the batteries.

The battery shall be installed in such a way as to readily facilitate safe testing. The electrical links between cells shall be fully insulated such that personal contact with live parts is not possible without removing shrouds. Batteries shall be installed in separate rooms or cubicles.

26.5.5 UPS systems

Where utilized, the battery capacity of the UPS shall be sufficient for the total shutdown of the applicable equipment in a safe, controlled, monitored and damage-free manner. The load shall be connected to the output of the inverter through a static power semi-conductor switch. In the event of a failure of the inverter output, or a drained battery, the load shall be switched automatically to the bypass supply, and vice versa on restoration. A make-before-break manual isolator shall completely bypass the static switch, such that all the UPS electronics are safely isolated for maintenance purposes. An alternative to the bypass system would be n+1 redundancy of the UPS.

26.6 Electrical/electronic equipment protection

26.6.1 Lightning and surge protection

Refer to 27.3 for details of lightning protection systems, including where an electronic system is connected to a data transmission line and for surge protection required for supply lines.

26.6.2 Electrostatic discharges (ESD)

Refer to 27.3 for details of ESD instrument protection against ESD protection for personnel and the earthed/bonding requirements.

26.6.3 Electromagnetic compatibility (EMC)

Instrumentation shall be selected that complies with the requirements for electromagnetic emissions and immunity of IEC 61000-6-4 and IEC 61000-6-2 respectively. All ESD equipment used by personnel on site shall conform to IEC 61000-4-2.

Cables shall be installed with sufficient separation to avoid electromagnetic interference. Installations, earthing and cabling shall comply with the general guidelines in IEC/TR 61000-5-1 and IEC/TR 61000-5-2, respectively. General disturbances can be limited by applying the measures in IEC 60204-1:2009, 4.4.2.

26.6.4 Electric arc welding

Refer to 27.3 for details of guidance on isolation and earthing to minimize the possibility of damage to C&I equipment from electric arc welding sets.

26.6.5 Earthing and bonding

Refer to 27.3 for instrument and safety earth and bonding for the protection of C&I equipment from earth faults.

26.7 Equipment protection

26.7.1 General

An automatic equipment protection system, together with the alarms and instrumentation to achieve equipment and personnel safety, shall be provided for the equipment and process. Automatic equipment protection systems shall be either active (e.g. starting or tripping of equipment items or moving valves or dampers) or passive (e.g. permissive signals for manual, sequence or other control actions). Active and passive protection systems shall be provided, where applicable, to the situation.

The protection system shall be capable of providing an appropriate response dependent on the severity and nature of the event or situation.

26.7.2 Protection systems

26.7.2.1 Flame monitoring

Direct or inferred (indirect) flame failure sensing shall be provided to monitor the presence of a combustion flame at the appropriate point during the start cycle and subsequently during normal operation. If the burner(s) fail to light within a safe time period, or extinguish while running, the fuel supply shall be shut off.

26.7.2.2 Bearing temperature

Gas turbines with main shaft bearings and active thrust bearing of the hydrodynamic type shall be equipped with temperature monitoring, which shall measure the bearing metal and/or return-oil temperatures, and actuate alarms and/or trips on abnormal temperature detected.

26.7.2.3 Air intake anti-icing

● If requested by the Purchaser, the Contractor shall install the necessary equipment to automatically control the action of any anti-icing system fitted to the gas turbine inlet air filtration system or intake bell mouth/first-stage blading (see 20.10).

26.7.2.4 Air intake pressure drop

The intake system shall be instrumented to provide indication of and initiate an alarm and subsequent trip on high differential pressure across the filter assembly. Where applicable, action may be taken to control the pressure drop before a trip is initiated.

● If requested by the Purchaser, the different pressure across each stage, where applicable, of the air intake assembly shall be monitored.

26.7.2.5 Exhaust temperature loading

An array of temperature detectors shall be provided to monitor the temperature of the gas turbine exhaust or the temperature before a separate power turbine. Sufficient detectors shall be provided to detect asymmetric failure or deterioration of the combustion system or turbine nozzles. An applicable alarm or trip shall be initiated if an abnormal temperature or temperature deviation is detected (see 21.7 for back pressure protection).

26.7.2.6 Overspeed protection

The overspeed protection system shall comply with the requirements of ISO 21789:2009 and 14.15 and shall employ a minimum of two independent sensors and circuits.

Following an overspeed, the turbine shall be capable of subsequent normal operation without the need for inspection. Attention is drawn to the necessity of ensuring that all coupled equipment, including auxiliaries electrically, mechanically or hydraulically coupled, withstand the corresponding overspeed.

Provision shall be made for testing of the overspeed trip. This may be a manual or automatic operation, and may or may not require interruption of normal operation. The test method shall be documented in the operating manual by the Contractor; normally testing shall be undertaken by simulation or depressing/reducing the trip setting until a trip occurs. Overspeed of the actual equipment shall normally be avoided.

● If requested by the Purchaser that an overspeed shall be undertaken at trip speed to demonstrate the function of the overspeed protection system, the Contractor shall provide a suitable procedure including optimum thermal condition and operating point of the gas turbine to minimize potential deterioration in the life of the equipment.

26.7.2.7 Combustor pressure

Where combustors operate at near flame extinction and the fluctuation of the heat release from the burners generate significant acoustic pulsation of the combustor space, detection is measured directly as dynamic pressure variation or as acceleration of the combustor casings. The Contractor shall provide, as a minimum, a system that detects and protects against damaging pressure pulsation or vibration.

26.7.2.8 Bearing pedestal vibration

As a minimum, bearing pedestal vibration (horizontal and vertical) shall be provided to protect the gas turbine, unless proximity probes are installed to monitor shaft displacement at the bearing. The instrument requirements are given in 26.2.6 and installation and monitoring requirements are given in Clause 31.

A single radial transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information on the magnitude of the machine vibration. Such usage shall be documented on the document data sheet.

26.7.3 Lubrication system

The C&I system shall provide for full automatic control, monitoring and protection. This shall cover the following conditions:

— starting of main pump, stand-by pump and emergency lube oil pump for test purposes, changeover of pumps, as necessary;

— starting, changeover of pumps, as necessary;

— running, continuous monitoring of supply pressures and temperatures;

— shutdown, including the starting of any emergency oil pumps, where applicable;

— any post-shutdown cool-down period;

— testing of emergency pump prior to start-up, where applicable.

The gas turbine supply oil temperature or bearing differential temperature shall be continuously monitored for operation within safe limits as specified by the Contractor.

26.7.4 Fuel system

26.7.4.1 General

The fuel supply shall be automatically controlled during starting and running so as to maintain the gas turbine within its safe operating envelope. Where necessary to meet environmental limits for emissions, the fuel supply shall also be controlled to meet combustion design criteria. The fuel system design shall comply with the requirements of ISO 21789:2009.

26.7.4.2 Operation on different fuels

Where applicable, the C&I system shall be capable of controlling the gas turbine on the applicable range of fuels, including gas fuels, liquid fuels, dual fuels (two independent fuels), mixed co-firing (proportional control of two fuels in parallel), low specific energy fuels and variable specific energy fuels. Any restrictions on transient changes in speed or load, the range limits for variable energy fuels and the need for different fuels for start-up shall be advised to the Purchaser by the Contractor (see Clause 8).

Where liquid fuels of a highly volatile nature are used, such as naphtha or gases with a density greater than air, special precautions may be necessary in accordance with ISO 21789:2009. These may include, but are not limited to, automatically operated fuel dump valves, segregation of fuel handling equipment, special purging routines to minimize hazardous situations, prevention of reverse and bi-directional flow and starting and shutdown using alternative fuels.

26.8 Fire precautions

26.8.1 General

Gas turbine equipment fire precautions shall comply with the minimum requirements of ISO 21789:2009.

● If requested by the Purchaser, fire detection shall be provided for C&I cubicles in which there is processing, data storage, power supply or other significant C&I equipment installed. A "fire alarm activated" lamp shall be fitted to the outside of each applicable cubicle.

Fire protection of the C&I equipment in work areas shall be by automatic fire detection, and automatic non-asphyxiating extinguishant or manual fire suppression.

26.8.2 Fire detection

For fire detection, see 14.3.

26.8.3 Enclosure fire precautions

For enclosure fire precautions, see 29.8.

26.8.4 Gas detection

For gas detection, see 14.5.

26.8.5 Smoke detection

For smoke detection, see 14.7.

26.9 Emission control

26.9.1 General

The gas turbine control system shall incorporate all the functions to sequence, monitor and control the combustion process as necessary to minimize emissions.

26.9.2 Exhaust emission monitoring

26.9.2.1 Continuous monitoring – exhaust emissions

● If requested by the Purchaser, the Contractor shall provide and install continuous emissions monitoring (CEM) equipment for the power generation package appropriately certified for the application. This shall include, as a minimum, the monitoring of NO_X, O_2 and CO.

● If requested by the Purchaser, the minimum monitoring requirements above shall be extended to monitor the following:

— CO_2;

— SO_2;

— H_2O (humidity calculated via ZrO_2 analyser for O_2 wet or direct measurement using a laser instrument);

— opacity/dust (with transmissometry instrument);

— THC (total hydrocarbons);

— NMHC (non-methane hydrocarbons);

— NH_3.

● If requested by the Purchaser, the CEM shall include systems that facilitate the calculation of cumulative mass releases of NO_X, CO, CO_2 and SO_2.

The equipment installed shall fulfil the requirements of the CEM system including monitoring flue gas mass flow rate, flue gas pressure, flue gas temperature and flue gas water vapour content. The sampling and access points shall meet the requirements of EN 15259-1:2007, Clause 6 and EN 13284-1:2001, 5.2, 5.3 and 5.4. Where compliance with other applicable regional or national requirements is required, these shall be specified in accordance with the document data sheet by the Purchaser. Monitoring locations shall meet ISO 10396 for gases.

● If requested by the Purchaser, a weather station shall be provided to applicable meteorological office standards for monitoring atmospheric conditions, including atmospheric pressure, atmospheric temperature, relative humidity, wind speed and wind direction. Atmospheric temperature and pressure shall be measured in accordance with ISO 2314:2009. Relative humidity shall be measured with an instrument with the capability of determining relative humidity within an uncertainty of 2 %.

The details of sampling facilities for particulate measurements shall be in accordance with EN 13284-1:2001, taking into account the gas flow stability criteria at the sampling points.

The output from any supplied emission monitoring equipment shall be displayed at the applicable controls HMI interface.

26.9.2.2 Predicted monitoring – exhaust emissions

● If requested by the Purchaser, and where the site required emission reporting obligations can be met based on a predicted exhaust emissions system based upon monitored turbine operating parameters, such a system shall be supplied with output displayed at the applicable controls HMI interface.

26.9.3 Periodic sampling

● If requested by the Purchaser, the Contractor shall provide appropriate emission sampling and measurement points for portable equipment.

26.10 Hazardous areas and certified equipment

Hazardous zones shall comply with the requirements of IEC 60079-10-1. Associated equipment shall comply with and be certified in accordance with the applicable standard in the IEC 60079-series.

Where regional, national or local regulations and legislation recognizes other established standards, such as the applicable clauses of NFPA 70 and NFPA 497, that achieve an equivalent level of safety and certification of equipment, these documents may be used as alternatives.

26.11 Control and instrumentation – maintenance and spare parts

26.11.1 General

In order to reduce the number of different items held as spare parts and to be maintained, the Contractor shall, wherever possible

— select identical equipment items for similar duties, and

— select equipment items from the minimum practicable range of type, class and manufacture.

● If requested by the Purchaser, where the Purchaser intends to maintain the C&I systems by holding an appropriate set of spare parts, identifying faults at the appropriate spare part level item and replacing the faulty part from the stock, the tender shall include costed proposals for suitable service arrangements covering replacements.

● If requested by the Purchaser, the tender shall provide a list of recommended C&I spare parts. This list shall include the number of the items of equipment installed, the service life, the lead time and the cost. The Contractor shall update and reissue the list of recommended C&I spare parts to the Purchaser prior to takeover of the equipment.

The Contractor shall supply all special tools and equipment required for installation, removal, routine maintenance, and testing (*in situ* and in-workshop) of C&I equipment and systems and provide details in accordance with the document data sheet. For the purposes of this requirement, special tools and equipment is defined as any tool or equipment that is not a commercially available catalogue item. All printer consumables and removable data storage media used by the C&I systems and other programmable systems shall be of internationally recognized industry standard, format and configuration and shall be available as standard items.

The Contractor shall provide a schedule of components which require periodic maintenance or replacement or where on-load maintenance is required in accordance with the document data sheet. This shall include the frequency of these operations and include estimates of maintenance man-hours and cost of components.

The Contractor shall identify any maintenance replacement operations which require shutdown of the process more frequently than the planned maintenance shutdowns in accordance with the document data sheet.

26.11.2 Equipment access

In order to ensure that there is adequate equipment access for the maintenance of C&I equipment, the recommendations in 30.6.15 should be applied.

26.12 Data communications

26.12.1 General

The Purchaser shall specify the communication facilities required for interfacing to a power plant DCS/data acquisition (DA) and storage system in accordance with the document data sheet. The Contractor shall specify the protocols that are available, the scope of data and control facilities available, data-transfer rates and time-tagging requirements and the acquisition of data required in accordance with the document data sheet.

As a minimum, the control system shall be designed to interface to a DCS/DA on-line, real time monitoring of data applicable to the operation and performance of the gas turbine systems including, but not limited to, the following:

— air inlet filter, lubrication oil, fuel;

— turbine compressor, combustor and turbine sections;

— parameters applicable to operating modes and change of states;

— parameters applicable to all alarms and trips;

— control loop information.

The DCS interface shall have capability so that the operator at the DCS can perform all normal control duties and the adjusting of operating parameters. The extent of data exchanged and the possibility of adjusting parameters shall be specified by the Contractor. Any command that would result in a distribution board being de-energized, supplies being paralleled, or equipment being overloaded shall cause a warning, identifying the consequence, to be displayed to the operator. The command shall only be actioned if the command is then re-confirmed. Any command that would result in unsafe operation shall be blocked by the protection systems and an appropriate signal sent to the DCS.

● If requested by the Purchaser, the Contractor shall offer a support service employing the use of telecommunications (modem interfaces) to aid in the identification of faults on gas turbines and their control systems, which require specialist diagnostic knowledge.

Where applicable, all emissions input data, calculated values, alarms and logs associated with environmental instrumentation described above shall be made available to a DCS and documented in accordance with the document data sheet.

The DCS shall be “open” to support the connection and use of third-party applications provided or developed by the Purchaser. These applications shall have full access to real time data. The operator shall be able to invoke and display data and formats from the third-party applications on the DCS console.

26.12.2 Data acquisition storage system

● If requested by the Purchaser, the Contractor shall provide a DA storage system for the gas turbine package that shall be capable of adequately storing data in sufficient resolution for event analysis and later investigations.

26.13 C&I system commissioning

C&I systems shall be commissioned on the basis of the following:

— end-to-end testing of all accessible inputs and outputs to the C&I protection functions that the C&I system carries out;

— testing of all interlocks, permissives and trips, if not already tested on control software tests or factory acceptance test;

— validation of the control system display format and the correct display of information;

— validation of control loops and control outputs, including the correct display of functions;

— testing of alarm functions, if not already tested on control software tests or factory acceptance tests;

— performance tests on each modulating control loop;

— functionality and performance of the DCS interface.

● If requested by the Purchaser, the Contractor shall ensure all equipment and analysis facilities are fully commissioned prior to the initial operation of each power plant item and “as-built” fingerprints are recorded.

27 Electrical system requirements

27.1 General requirements

Electrical and electronic equipment described in Clause 26 of this International Standard operate with low power and voltages (e.g. control equipment, sensors) and are typically limited to such equipment that is associated with the protection and control of the gas turbine package.

The electrical equipment described in this clause typically consists of equipment associated with auxiliaries and the distribution, switching and conversion of electrical power (e.g. cables, switches, contactors, switchgears, motors, UPS, batteries).

The provision of electrical power for the gas turbine package and auxiliaries and common station services related to the gas turbine package shall be documented by the Contractor on the document data sheet. Any variations required to the provisions shall be documented by the Purchaser in accordance with the document data sheet.

The electrical system requirements subject to this International Standard shall be therefore limited to the following:

— design, layout and redundancy;

— earthing and lightning protection, equipotential bonding;

— power supply requirements;

— low voltage (LV) switchgear and control equipment;

— DC distribution, if applied;

— battery including battery charger, if applied;

— control system power supply;

— conductors and cables, installation requirements;

— wiring practices;

— electric motors;

— protection against electric shock.

Where applicable, requirements shall comply with IEC 60204-1:2009.

The equipment provided shall be safe, fit for purpose, easy to maintain and have appropriate reliability, availability and operational flexibility. The apparatus shall be of designs proven in a power station operating environment.

The grid interface, the auxiliary power supply interface and the gas turbine package electrical system designs shall be such that in the event of electrical faults occurring in the grid systems or the electrical systems of the power generation package, equipment will be capable of withstanding the most onerous faults within their assigned performance ratings and the faulty portion of the system shall be disconnected by appropriate electrical protection device.

All supplied electrical equipment shall be capable of operating continuously under actual service conditions within the grid frequency range, together with any voltage between +10 % and −10 % of the nominal voltage, normal operating voltage deviation shall be between +5 % and −5 % as common practice in power plants (the generator voltage variation is usually between +5 % and −5 %), this voltage variation should be the basis for voltage dip during start of motors. The equipment shall be capable of continuous operation at the specified lower end of the frequency range. The installations and equipment shall be designed for such indoor and outdoor environmental operating conditions as appropriate to their location. Anti-condensation heaters may be required depending on the place of installation.

The design of the electrical equipment shall ensure that all operating and maintenance activities can be performed safely and conveniently. The electrical equipment shall be arranged in a manner that it can be easily erected, connected, operated and maintained without creating hazards.

All devices installed in electrical cabinets shall be labelled and all terminations on devices shall be marked in accordance with the documentation. Each cable shall have a number or equivalent.

The numbering or equivalent of wires for the connection of devices in electrical cabinets shall be agreed between the Purchaser and the Contractor at the tendering stage.

For the purposes of this specification, voltage levels are defined in accordance with IEC 60038 as

— low voltage (LV), between 50 V to 10 00 V AC, and 75 V to 1 500 V DC, and

— medium voltage (MV), 1 kV up to and including 35 kV AC.

High voltage (HV) 35 kV to 230 kV and extra high voltage (EHV) are considered outside of the scope of this International Standard.

All AC electrical systems shall be based on the nominal grid frequency and comply with IEC 60038.

No apparatus shall cause radio or television interferences in excess of the limits specified in IEC 61000-6-3 and IEC 61000-6-4.

Proper regard shall be given to the electro-magnetic compatibility (EMC) of high current at grid frequency and low current very high frequency (VHF) electronic equipment which may exist on a generating unit site. All equipment and apparatus shall comply with the EMC requirements of IEC 61000-6-3 for emissions and IEC 61000-6-4 for immunity.

The power plant shall also comply with the standards for human exposure to electromagnetic fields, as described in IEC 61786 and IEEE C95.3.

Electrical equipment installed in explosive gas atmospheres shall comply with the requirements of ISO 21789:2009.

Where applicable, equipment shall be provided with warning signs in accordance with ISO 12100. Graphical symbols used shall comply with IEC 60417 and be attached in a compartment or on the outside of an assembly. In locations where hazards exist, or dangerous situations may be created, warning signs or caution notices shall be installed in accordance with the regulations and legislation of the country where the equipment is installed.

● If requested by the Purchaser, the Contractor shall perform all design studies required to determine the necessary parameters and settings and to demonstrate to the Purchaser that the systems provided are adequate. Such studies, documented in accordance with the document data sheet, shall take into account the Contractor's scope, including

— load flows, fault levels (at all voltage levels),

— dynamic/transient performance, harmonic study, and

— protection setting and grading.

27.2 Design, layout and redundancy

The design and layout of the electrical systems of the gas turbine package shall be such that reasonable segregation is achieved between the respective power generation package and between the power generation package and power station services, where practical, due to the configuration of equipment. The Purchaser shall document, in accordance with the document data sheet, the Purchaser's requirements for redundancy for the electrical supplies within the Contractor's scope of supply, including but not limited to, LV bus and batteries.

27.3 Earthing and lightning protection, equipotential bonding

All electrical systems of the gas turbine package shall be equipotential bonded in accordance with IEC 60204-1:2009, shall be connected to earth references provided by the Purchaser and shall be in general compliance with IEC 60364-1. Minimum cross-sections of the earth conductors shall be in accordance with power plant earthing design calculation in accordance with EN 50522 and IEC 61936-1 for the applied voltage levels in the gas turbine package.

The equipotential bonding of the gas turbine package shall ensure that the maximum touch voltage does not exceed 50 V between earthed devices to which personnel may make simultaneous contact.

A lightning protection zone (LPZ) in accordance with IEC 62305-1 LPZ 1 shall be provided in rooms or areas where control system cubicles are installed.

At the interface point between LPZ 0 and LPZ 1, in accordance with IEC 62305-4, all penetrating metal components shall be bonded to the equipotential bonding system preventing external lightning currents entering a building by being directly conducted to ground.

The following components shall be bonded at the entering point:

— metal pipes without isolation barrier, e.g. gas, water, etc.;

— metal ducts, e.g. air ducts, exhaust gas ducts, HVAC ducts;

— metal cable trays/risers and metal cable conduits.

Steel columns and metal frames shall have as minimum one visible connection to the grounding system or the connections to ground, or between elements shall be verified by resistance measurements to have low resistance. A measurement protocol shall be available upon request. The type of construction shall ensure electrical continuity or bonding straps shall be fitted between elements. Embedded base-frames for the control system and electrical cubicles shall be directly connected to earth or to the floor reinforcement. At least two interconnections at opposite sides shall be applied per base-frame structure.

The panels, terminal boxes and cabinets for electrical components for low or medium voltage levels shall be connected to earth. Switchgear and control equipment usually consist of several cubicles, therefore it is recommended to provide two connections to earth at the opposite sides of the arrangement.

Instrument earths shall comply with one of the following requirements:

— isolated separated instrument earth system with one connection between earth and instrument reference conductor, while the instrument cable sheath is connected to the reference conductor at the control system cubicle only;

— distributed instrument earth system with multiple connections between earth and instrument reference conductor, while the instrument cable sheath is earthed at both cable ends (some field instrumentation do not intentionally allow the earthing of the cable sheath in the field).

The Contractor shall document the instrument earth to be used in accordance with the document data sheet.

The LV AC system shall be solidly earthed (TN network) in accordance with IEC 60364-4-41. The DC system > 50 V, if applied, should be insulated (IT network). The DC power supply of the control system shall be solidly earthed. HV generator neutral shall be operated either insulated with earthing transformer on the line side or earthed by high impedance transformer. LV generator neutral shall be solidly grounded.

Where applicable, lightning protection systems shall be applied in accordance with IEC 62305-1.

27.4 LV power supply requirements

The Purchaser shall define for the external electrical supplies the voltage level and frequency, and the variation thereof (typically 690 V or 400 V/480 V ± 10 %, 50 Hz/60 Hz +3/-5 %) on the information data sheet. In addition, the Purchaser shall define the short circuit level of the supply source with the minimum and maximum values at the LV system interface.

The Contractor shall define steady-state load, maximum load and transients load (starting with the biggest motor or group of motors) required for the operation of the gas turbine package on the information data sheet.

A general requirement is for all equipment to be designed so that interruptions or disturbances which occur in electrical supplies do not endanger personnel or damage equipment. Voltage dips to 85 % of the nominal voltage lasting for maximum 1 s at the incoming terminals of the gas turbine package. LV switchgear or control equipment shall not cause an interruption of the operation of the gas turbine package.

The power supply shall be monitored for low voltage level and phase rotation.

The Purchaser shall specify requirements for metering and measuring devices on the information data sheet.

The power supply disconnecting device shall meet the requirements of IEC 60204-1:2009, Clause 5 and electrical protection shall be coordinated with the upstream protective device.

Electrical controls in switchgears and control equipment shall be either AC or DC powered. In the case of DC power, the supplier shall provide a battery charger and battery, the DC voltage level shall be in accordance with the preferred values in IEC 60038:2009, Table 6. The Contractor shall advise the Purchaser where voltages are in the supplementary range of IEC 60038:2009, Table 6 on the information data sheet.

● If requested by the Purchaser, a surge protection device shall be supplied for the incoming LV AC supply in accordance with IEC 61643-12.

The harmonic distortion of the external LV system shall be as for public networks in accordance with IEC 61000-2-2, class 2, while the harmonic distortion emitted by the gas turbine package LV system shall be as for industrial networks to IEC 61000-2-4:2002, class 3.

If the gas turbine package requires a high voltage MV (typically 6 kV to 11 kV) power supply (typically for static frequency converter or excitation system or fuel oil injection pumps of high rating gas turbine packages), the Contractor shall specify the load requirements (see above), while the Purchaser specifies voltage and frequency and the variation thereof on the information data sheet.

The Purchaser shall provide minimum short circuit power to minimize the harmonic distortion in the 6 kV to 11 kV system to THD ≤ 10 %.

Since the interface is typically the 6 kV to 11 kV connection to the transformer or the motor terminals, close interface coordination is required for the power connection (typically by cable), control and electrical protection.

27.5 LV switchgear and control equipment

LV switchgear and control equipment shall comply with the applicable parts of IEC 60439 and IEC 60947.

LV switchgear consists of, for example, contactors, fuses, etc.

In addition to LV switchgear, control equipment has integrated control units.

Requirements regarding the following shall comply with IEC 60204-1:2009, Clause 11:

— location and mounting;

— degree of protection;

— cabinets, door and openings;

— access to control equipment.

Requirements regarding protection of equipment are given in IEC 60204-1:2009, Clause 7.

Electrical control voltage can be either AC, see IEC 60204-1:2009, 9.4.3, or DC.

When DC control voltage is applied, where applicable for safe operation, motors controlled by the switchgear and control equipment shall be automatically disconnected in case the supply voltage falls below an acceptable value (typically 80 % to 85 % of the nominal supply voltage level).

Where applicable for protection of the gas turbine package equipment and provided that a hazardous situation is not created, the control of dedicated motors (e.g. drives for turning gear operation) remain in the ON position and they are restarted when the voltage recovers or the stand-by supply becomes effective (e.g. stand-by diesel generator set).

The low voltage level of at least incoming feed(s) shall be monitored.

Short circuit protection can be either by fuse or a miniature circuit breaker (MCB)/moulded case circuit breaker (MCCB).

Each circuit, sub circuit and control loop shall be individually protected. However, where a control loop contains a number of items that can be used independently, consideration shall be given to the protection and isolation of individual items.

Motor starters shall be preferably of a withdrawable design, providing an "operation position", "test position" (main circuit contacts are disconnected, while control circuit contacts are connected) and a "disconnected position".

Each circuit shall have adequate facilities to prevent inadvertent energization (e.g. by use of padlocks).

Each shutdown device, system or actuator shall be individually protected where practical. Where a shutdown system comprises a number of actuating devices, and supply failure to part of a system rather than the whole system would itself create a hazard, the system rather than the individual items shall be protected.

Isolation of each individual panel-mounted instrument shall be provided by a double-pole switch, MCB, disconnecting plug or isolating terminals as appropriate. Supplies to non-critical panel instruments may be grouped (preferably not more than six) to one supply circuit.

27.6 DC distribution

DC distributions shall be in accordance with the applicable parts of IEC 60439 and IEC 60947.

DC distributions may serve for the power distribution or control of the following:

— electrical control voltage;

— solenoid valves, if not operated by control system;

— emergency lube oil pump, if applicable;

— emergency seal oil pump, if applicable;

— power supply DC/DC inverters for control system power supply, if no separate battery for control system power supply is used;

— power supply for the DC/AC inverter uninterruptable AC bus or AC consumers.

The following requirements shall comply with IEC 60204-1:2009, Clause 11:

— location and mounting;

— degree of protection;

— cabinets, door and openings;

— access to control equipment.

Requirements regarding protection of equipment shall comply with IEC 60204-1:2009, Clause 7.

It is recommended to sectionalize the DC distribution, especially when no separate battery is provided for control system power supply.

Low voltage level of each bus section shall be monitored.

Short circuit protection can be either by fuse or MCB/MCCB.

Each circuit, sub circuit and control loop shall be individually protected where practical. However, where a control loop contains a number of items that can be used independently, consideration shall be given to the protection and isolation of individual items.

Overload protection for the emergency lube oil pump, if applied, shall be designed to ensure protection can only operate where no other alternative exists.

27.7 Battery including battery charger – DC/AC converter

Batteries shall comply with the relevant parts of IEC 60896, battery chargers shall comply with IEC 60146-1. Battery installation and maintenance shall comply with EN 50272-2.

EMC requirements shall be in accordance with IEC 62040-2, IEC 61000-6-2 or IEC 61000-6-4.

Battery capacity shall be determined on the basis of the amount of energy needed for the following:

— safe shutdown of the gas turbine package until the shaft comes to stand still, while no AC supply is available;

— maintaining control and protective functions and the power supply to the control system, where separate control batteries are not provided, in which case the applicable requirements of 26.5.4 and 26.5.5 shall be applied;

— keeping the operator interface in operation for a time to be defined by the Purchaser where this is supplied from the uninterrupted AC bus.

The Contractor shall specify the design life of the batteries.

The battery shall be installed in such a way as to allow easy maintenance. The electrical links between cells shall be fully insulated such that personal contact with live parts is not possible without removing shrouds. Batteries shall be installed in separate rooms or cubicles.

The battery chargers shall have float and boost charging facilities and constant current charging IU characteristic.

The rating of the battery chargers in float charging mode shall cover the load of DC consumers being in operation when AC supply is available and the gas turbine package is in operation at maximum output or turning gear operation.

DC/AC inverters supplying the uninterrupted AC bus or AC consumers shall comply with IEC 62040-1.

The load shall be connected to the output of the inverter through a static power semi-conductor switch. Where a redundant UPS is supplied, in the event of a failure of the inverter output, or low battery voltage, the load shall be switched automatically to the bypass supply, and vice versa on restoration. Where no redundant UPS is supplied and battery voltage is low, a controlled shutdown shall be implemented.

A make-before-break manual isolator shall completely bypass the static switch, such that all the DC/AC inverters are isolated for maintenance purposes.

A battery low alarm shall be available from the battery system to allow shutdown in the event of battery faults or a charge level that will not support the operation of DC-driven emergency pumps if required to shutdown the system without damage on the loss of AC.

The Contractor shall advise the Purchaser where a diesel generator is to be supplied in order to limit the size of UPS and battery systems. Diesel generator systems shall start automatically if needed. There shall be facilities for testing and load runs. The voltage and load control shall not require operator action while running. Fuel tank capacity shall be sufficient for the shutdown scenarios described in the preceding sections, without refilling.

27.8 Control system power supply

Refer to 26.5 for control system power supplies which may be achieved by DC/DC inverters, where applicable, supplied from the DC distribution (see 26.5.4 and 27.6).

Standards referenced in 27.7, where applicable, shall apply for control system power supplies.

27.9 Conductors, cables and wiring practices general

Cables and wires shall comply with the relevant parts of IEC 60502. Other standard cable types may be used if required by environmental conditions. Flame propagation requirements shall be in accordance with the relevant part of IEC 60332.

Typical power cable types in power plant installation are as follows:

— Polyvinyl Chloride (PVC) insulated, PVC outer sheath – YY;

— Cross Linked Polyethelene (XLPE) insulated, PVC outer sheath – 2XY;

— XLPE insulated, Low Smoke Zero Halign (LSZH) outer sheath – 2XH.

Environmental conditions may require other cable types.

The cross-section of LV power cables shall be designed in accordance with the applicable IEC standards.

Colour coding shall comply with IEC 60304 or IEC 60445 and IEC 60757.

Wiring in assemblies shall have different colours for circuits with voltages of < 60 V and > 60 V.

Conductors in multi-core power cables shall serve for one circuit only, exceptions may be allowed for control purposes.

The minimum cross-section of cables and wires shall be according IEC 60204-1:2009, 12.3, Table 5.

The routing and separation of signal cables from power cables shall follow the guidance in IEC 61918.

27.10 Conductors, cables and wiring practices outside cabinets

Cable routes (trays, troughs and risers) shall be preferably hot dipped galvanized (HDG) steel with a zinc thickness suitable for the environment of the installation. Cable routes shall be connected to earth at both ends of the installation, so that they are part of the equipotential bonding.

Covers on trays and risers for mechanical protection are recommended for certain areas (moving parts, etc.).

Fire barriers shall be provided on cable routes crossing different fire protection areas in accordance with IEC 60079-14:2013 and/or NFPA 70.

Physical separation of cables and/or cable routes for redundant components is not required unless otherwise specified by the Purchaser in accordance with the document data sheet.

Cable routes and conduits shall be arranged so that they do not prevent access to devices as far as practical, especially equipment being subject to regular maintenance.

HDG conduits are recommended for mechanical protection of the cables installed outside of cable routes. It is recommended to apply separate conduits for different voltage levels.

27.11 Wiring inside cabinets

Wiring inside cabinets shall be in accordance with IEC 60204-1:2009, 12.3.

27.12 Electric motors

Electric motors shall comply with IEC 60034-1 or NEMA MG1 equivalent.

Further requirements are given in IEC 60204-1:2009, Clause 14 or NEMA MG1 equivalent.

The following information shall be documented in accordance with the document data sheet.

— The temperature rise to insulation class F, utilization to class B when operating at rated power, voltage and frequency. In case of voltage and frequency deviation the temperature rise of class B can be exceeded, however, class F temperature rise shall not be exceeded.

— The minimum voltage at the motor terminals at which a motor shall accelerate to nominal speed.

— The minimum voltage at the motor terminals for limited time at which the motor shall not fall below its pull out torque.

— The maximum starting current ratio (applied usually for HV motors only).

The degree of protection for the motor housing shall be a minimum of IP54 in accordance with IEC 60034-5, IEC 60529:2013 or NEMA equivalent.

DC motors for the emergency lube oil pump and emergency seal oil pump, where applicable, shall be to the manufacturer’s standard. Motors of rating equal or less than 5,5 kW which form a special assembly with the driven equipment shall be to the manufacturer’s standard.

Coordination with the power supply system and the design of the power cables is required.

27.13 Junction boxes and cabinets

Where power and electronic equipment (e.g. for controls, etc.) are installed in the same cabinet, internal partitions shall be provided. Particular care shall be taken considering separation and screening of measuring circuits.

Junction boxes and cabinets shall be suitable for the environment at the place of installation. Minimum degree of protection, in accordance with IEC 60529:2013 or NEMA equivalent shall be as follows:

— IP20, when installed in an electrical equipment room;

— IP54 or NEMA equivalent, when installed in non-electrical equipment room or installed outdoor or under outdoor climate conditions.

Equipment installed outdoors shall be protected against solar radiation and heavy rainfall by means of adequate covers or a roof.

Cable entry shall be preferably from the bottom by applying appropriate cable glands.

Where necessary, when installed in non-air-conditioned rooms or outside, space heaters shall be applied.

Terminals shall comply with IEC 60947-7-1.

An air gap of at least 2,5 mm or a partition plate shall be applied between terminals of different voltage level. Terminals of circuits (U > 60 V) which are still alive when the power disconnecting device is OFF shall be covered and appropriately labelled.

Sufficient distance between cable entry and terminal strip, between wiring trunks and terminal strips, and between terminal strips and installed devices shall be provided.

All live parts > 60 V shall be adequately covered or the accidental contact is prevented by the design of the installed equipment.

● If requested by the Purchaser, spare terminals of 10 % shall be provided.

27.14 Protection against electric shock

Requirements regarding protection against electric shock shall comply with IEC 60204-1:2009 and IEC 61140.

27.15 Trace heating

Where trace heating is required on electrical equipment it shall be fitted in such a manner to enable easy removal of the applicable equipment for maintenance and shall not be capable of providing enough heat to damage the trace heated equipment under any process and fault conditions.

27.16 Grid codes

The Purchaser shall specify and supply in the identified language in accordance with 15.2.3 the applicable regional or national grid codes and all associated ancillary service agreements/bilateral connection agreements and any other agreements that may affect the operation of the power generation package. The Purchaser is required to comply with regional or national requirements in accordance with the document data sheet.

28 Maintenance requirements

28.1 General

For the purposes of this International Standard

— routine maintenance is defined as those activities that can be carried out safely with the gas turbine package operating and synchronized with the grid or network, and

— scheduled maintenance is defined as work that can be carried out only with the gas turbine package shutdown.

28.2 Design for maintenance

The gas turbine package, systems and auxiliary equipment shall be designed for all scheduled maintenance activities either *in situ* or for removal to a workshop within the site or to a works. The foreseeable risks associated with maintenance shall be identified and mitigated by the design of the gas turbine package, systems and auxiliary equipment, and associated maintenance tools such that adequate risk reduction is achieved. The mitigation shall include access to power plant/equipment items for maintenance and the ability to remove power plant/equipment to a maintenance area or to transport to a works.

The operating and maintenance manuals shall describe the maintenance activities required for the power generation package for which training is available (see 28.8). They shall also specify the procedures and tools required for these tasks.

28.3 Maintenance strategy (*in situ* or at works)

The overall strategy for the machine maintenance shall be described in accordance with the document data sheet with particular emphasis on which tasks can be completed *in situ* (at site) compared to the tasks that need either local workshop facilities or that require overhaul at the Contractor's service works.

28.4 Maintenance planning (scheduled maintenance, scheduled inspections)

The Contractor shall supply a maintenance schedule covering all equipment within the Contractor's scope of supply in accordance with the document data sheet.

The Contractor shall provide, in accordance with the document data sheet, a programme showing the expected scheduled maintenance related to hours or cyclic events. The programme shall cover the gas turbine design life in accordance with 18.1.1.

The Contractor shall provide the following information related to scheduled maintenance inspections in a single document in accordance with the document data sheet:

— nature of inspection (borescope or inspection requiring casing removal or rotor removal), at tender stage;

— detailed scope of inspection, including scope of inspection by the Purchaser's trained staff and scope of inspection supervised or undertaken by the Contractor's staff, at contract stage;

— projected inspection downtime based upon normal shift patterns at tender stage.

Where necessary, the Contractor shall supply suitably competent personnel to undertake or supervise maintenance activities that are outside the capabilities of the Purchaser's trained personnel.

28.5 Parts repairs and replacement

28.5.1 Repair

The Contractor shall provide, in accordance with the document data sheet, a schedule of the repair and replacement interval for all lifed components and high value components. During contract negotiations agreement shall be reached as to the title of parts provided for repair or replacement regardless of the type of maintenance service provided.

The life of the hot gas path components and their repair capability is a major input to the gas turbine power plant whole-life economic assessment carried out by the Purchaser during the selection of the gas turbine power plant during procurement.

Where the Contractor states that a repair cycle is necessary to achieve the full, expected component life, the Contractor shall document the current repair experience based upon their fleet experience. This shall be provided in accordance with the document data sheet.

28.5.2 Component lives

28.5.2.1 General

All lifed components (as defined in 3.10) with planned inspections shall have a clear and unique identification that is not shared with other components, such as a serial number. The identification shall be marked on a visible surface of the component.

The Contractor shall provide a list of the expected inspection intervals and the ultimate life for all the gas turbine components, in accordance with the document data sheet, that are inspected and assessed as lifed components. This information is necessary for safe and efficient control of components within the gas turbine. The Contractor shall ensure that information provided to the Purchaser regarding scheduled repair and replacement (life) intervals for components corresponds with service or field instructions that impact component life.

28.5.2.2 Condition based maintenance

The Contractor shall document whether it is their normal practice to assess and replace components based on service condition and not according to a published schedule in accordance with the document data sheet.

Where applicable, the Contractor shall provide documentation for the components subject to condition based maintenance (CBM) at the tender stage.

CBM is the replacement of components when their observed condition at service intervals dictates that the components are not suitable for a further operating interval. The operating hours or starts at which this occurs may differ according to duty and site conditions. The Contractor shall document whether it is their normal practice to include CBM and which components are subject to CBM in accordance with the document data sheet.

28.6 Tools

● If requested by the Purchaser, lifting equipment and tooling, for which training in its use is available (see 28.8), shall be supplied by the Contractor to undertake applicable maintenance and inspection activities. For sites having multiple, identical machines the quantity of tools required shall be defined by the Purchaser.

● If requested by the Purchaser, lifting equipment and tooling necessary to achieve the downtimes during scheduled maintenance activities shall be supplied by the Contractor, prior to the start of activities, to avoid delays at site. For sites having multiple, identical machines the quantity of tools required shall be defined by the Purchaser.

28.7 Spares

28.7.1 General

A full listing of recommended spare parts for the post-commissioning period and subsequent operation shall be supplied for the machine for planning purposes in accordance with the document data sheet. This list shall include all consumable spares and maintenance spares required for the power generation package, including the part description and number of parts required. Costs for all major consumable spares and maintenance spares for the power generation package and controls shall be supplied in accordance with the document data sheet.

The Contractor shall, for at least 10 years after the contract signing date, supply suitable replacement or repaired components.

28.7.2 Strategic spares

After discussion with Purchaser on their gas turbine package availability requirements, the Contractor shall provide, in accordance with the document data sheet, a list of strategic spares for the gas turbine package. Strategic spares are defined as those required to maintain availability in the unlikely event of the failure of an item with a very long supply lead time. The Contractor shall use their fleet knowledge and experience of the gas turbine package to determine the contents of this list.

28.8 Training

The Purchaser and Contractor shall agree on the required extent of any training for the Purchaser's operating and maintenance personnel. Specific training covering tasks associated with the gas turbine core requiring appropriately qualified and experienced Purchaser personnel and the conditions on how this should be undertaken shall be agreed separately with the Contractor.

The Contractor shall have training courses available for tasks to be performed by the Purchaser and requiring special knowledge covering the following:

— operator's tasks, including controls HMI usage;

— gas turbine package routine maintenance, including all consumables;

— routine maintenance and calibration requirements covering all C&I and associated protection devices;

— power generation package isolations;

— power generation package auxiliary systems maintenance, including all routine maintenance task and consumables;

— inspection requirements during operation;

— basic shutdown fault analysis and rectification;

— use of the Contractor's purchaser support centre.

● If requested by the Purchaser, the Contractor shall provide sufficient training for the Purchaser's staff to attain the competencies required to carry out the above on-site maintenance, safely and with no risk to the power generation package.

28.9 Outage maintenance

28.9.1 Programmed maintenance

28.9.1.1 General

● If requested by the Purchaser, a long-term programme (LTP) for maintenance, spare parts, repairs, different warranties and remote services shall be offered.

Where a long-term programme is not requested, the Contractor shall provide details of alternative maintenance programmes that include the maintenance scope and planning requirements given in 28.9.3 in accordance with the document data sheet.

28.9.1.2 Purchaser maintenance requirements

Where the option for an LTP is specified, the Purchaser shall specify the requirements regarding the following items in accordance with the document data sheet:

— the time period for the LTP in years;

— major components included in the LTP;

— total number of separate gas turbines required in the power plant;

— number of gas turbines from the total number required to be in concurrent operation to fulfil the load demand;

— total concurrent operating hours required per year;

— projected number of starts required for each gas turbine per year;

— required availability according to 28.9.1.4;

— required reliability according to 28.9.1.5;

— projected degradation according to 28.9.2.

28.9.1.3 Service level requirements

● If requested by the Purchaser, service agreements shall be offered on one or more service levels with increasing scope. Common to each service level shall be a 24 h global helpdesk service giving access to a network of specialists and on-line tools connected to the control system for advanced customer support during operation disturbances. Scope may vary according to the depth and extent of performance analysis and condition monitoring, and the method and speed of reporting.

28.9.1.4 LTP availability requirement

The availability factor shall be as defined in 13.1.4.

● If requested by the Purchaser, the details of summated individual values of FOH, POH, PH and AH used for the availability calculation shall be documented in accordance with the document data sheet.

28.9.1.5 LTP reliability requirement

The reliability factor shall be as defined in 13.1.2.

● If requested by the Purchaser, the details of summated individual values of PH, POH, RSH, SH, FOH and FO used for the reliability calculation shall be documented in accordance with the document data sheet.

28.9.2 Degradation after maintenance period

● If requested by the Purchaser, degradation in % upon completion of overhauls shall be measured as degradation in the power rating and heat rate as actual performance compared to the performance established during the new power generation package performance acceptance test.

28.9.3 Maintenance scope and planning

The Contractor shall specify and describe in detail in the maintenance manual the items in 28.3 to 28.8, where each of these are included in the project scope, in addition to the specific items listed below:

— planning, work methods and procedures related to the actual service;

— full QA documentation with non-destructive testing (NDT) records, inspection results and dimensional measurements;

— project management, including regular Purchaser reviews;

— requirements on how to record the operation and maintenance.

28.10 Maintenance documentation

All scheduled maintenance requirements that require the machinery to be shutdown shall be identified within the maintenance manuals.

Operating and maintenance manual content shall include all essential general data and information, descriptive matter, operating instructions and maintenance information necessary to enable the machinery to be operated and maintained properly and effectively. The contents shall cover all the power generation package items as appropriate for which training is available (see 28.8).

The manuals shall alert the Purchaser to any hazards inherent in the equipment or likely to arise in the implementation of operating or maintenance procedures.

The nomenclature, terminology and abbreviations used throughout the manuals shall be consistent and conform to recognized engineering terms.

The required format(s) for maintenance manuals is shown on the data sheet index.

Maintenance instructions shall include the following:

— gas turbine package item description and nameplate data;

— operator’s tasks, including controls HMI usage;

— gas turbine package routine maintenance, including all consumables;

— routine maintenance and calibration requirements covering all C&I and associated protection devices;

— power generation package isolations;

— power generation package auxiliary systems maintenance, including all routine maintenance tasks and consumables;

— inspection requirements during operation;

— basic shutdown fault analysis and rectification;

— details of tooling requirements;

— use of the Contractor’s purchaser support centre;

— torque settings or extensions of all fasteners;

— recommended spare parts list.

● If requested by the Purchaser that information and associated tooling is required for the Purchaser to undertake major maintenance activities, this shall be undertaken by prior negotiations and agreements to ensure the necessary confidentiality is achieved. This shall ensure that such information, equipment and tools that may be required and which are considered proprietary by the Contractor are handled in such a manner, due to the investment undertaken by the Contractor, that the information does not become available to third parties who would have an unfair commercial advantage having not invested in acquiring the necessary knowledge. Such information may include the following:

— rotor alignment procedure;

— rotor disassembly;

— vane carrier positioning;

— cleaning of casing and pipework scale to prevent cooling hole blockage;

— details of all necessary clearances, tolerances and dimensions for the satisfactory operation of the gas turbine core when disassembled and reassembled;

— details of all special tools required;

— full step-by-step procedures for the dismantling and reassembly of the gas turbine core, including details of special procedures;

— rotor blade tip grinding and prevention of cooling hole blockage;

— maintenance of IGV system to prevent stall;

— any special surface finish or painting repair procedures;

— management of rubbing contact during commissioning;

— compressor blade minimum critical defect size and measurement of defects;

— details of materials employed;

— welding procedures.

Where necessary to ensure tasks are undertaken without introducing risks, works shall be supervised by the Contractor's personnel.

29 Enclosures

29.1 General

Enclosures are used to enclose the gas turbine package, exhaust shroud, load compartments, including the generator and gearbox, and associated auxiliary equipment.

Enclosures shall be supplied, where applicable, to provide the following:

— environment protection for equipment located outdoors;

— artificial ventilation to prevent the formation of flammable gases, vapours or mists where the risk of ignition exists;

— artificial ventilation to dissipate heat from hot surfaces;

— attenuation of noise levels to defined limits;

— compliance with ISO 21789 with respect to the safety aspects of enclosures.

Enclosures are normally of steel construction but other materials may be specified by the Purchaser using the options data sheet (see 29.2).

Where the gas turbine is installed in a building used as a gas turbine hall, a separate gas turbine enclosure may not be required. In this case, the clauses applicable to this type of installation shall be implemented.

● The Purchaser shall select on the options data sheet the type of enclosure, if required, and its location. Where more than one type of enclosure is required, the data sheets applicable to Clause 29 shall be repeated for each enclosure type required.

29.2 Construction

29.2.1 General

The construction shall comply with the applicable ISO construction code or equivalent codes and standards used by the Contractor that provide an equivalent standard of design and stability.

Construction methods may require partial or complete assembly of the enclosure at site. Enclosures which may be required to be removed for scheduled maintenance shall be capable of being readily dismantled and reinstated without damage. Panel removal shall not be required for routine maintenance.

The construction of the enclosure shall ensure the external weatherproofing (see 29.2.2) of the equipment while allowing maintenance access (see 29.4) where the enclosure is located outdoors.

Materials shall be selected for construction of the enclosure that are suitable for the design life of the gas turbine package, with minimal maintenance, and that are not susceptible to corrosion under the prevailing site conditions.

● The Purchaser shall select the outer skin or panel material to be used from the options available on the options data sheet.

● The Purchaser shall select the materials of construction for the structural framework of the enclosure on the options data sheet.

● If requested by the Purchaser, closed circuit television (CCTV) shall be installed to monitor the gas turbine enclosure together with adequate lighting, located either inside or outside the enclosure with a view through suitable window(s). The CCTV shall have adequate field(s) of view to monitor the internal space of the enclosure.

● If requested by the Purchaser, gas turbine enclosure window(s) shall be supplied. The size, position and quantity shall be suitable for the field of view across the gas turbine. The windows shall be preferably installed within an access door, at a height considering the local grade level. See 29.5 for access requirements.

29.2.2 Weatherproofing of enclosure

Machinery shall normally be protected from the environment by means of an enclosure, the design of which needs to take into consideration the degree of weather exposure particular to the site.

Enclosure design shall be suitable for the conditions defined in Clause 6 and associated data sheets. Water or dust ingress through the walls or roof panel joints is unacceptable. The use of sloped surfaces to reduce pooling of water on large horizontal surfaces shall be considered. Rain or melt water should be directed to a suitable drainage system.

29.2.3 Acoustic and heat insulation

For the Purchaser's noise requirements refer to 7.3 and 33.4.

Where high (or low) temperature surfaces penetrate the enclosure walls, suitable thermal protection or guarding shall be used to prevent accidental injury to personnel. Asbestos-based materials shall not be used and ceramic fibre materials avoided, whenever practicable to do so, for all thermal and acoustical insulation applications.

If ceramic fibre materials are used they shall be suitably enclosed to minimize personnel exposure.

The Contractor shall provide details of the acoustic insulation material on the information data sheet for applicable enclosures.

29.2.4 Ventilation and explosion prevention and protection

Enclosures shall be ventilated where there is a requirement to the dilution of hazardous atmospheres, pressure build-up or to release heat. Natural ventilation may provide adequate ventilation to release heat or pressure build-up or the dilution ventilation of potential hazardous atmosphere in accordance with ISO 21789 and 10.1. If additional ventilation is required for heat removal or dilution ventilation of potential hazardous atmosphere in accordance with codes and standards, a forced ventilation system shall be provided in accordance with ISO 21789:2009, 5.16 and 5.17 (see 14.4).

Where the enclosure panels are required to be removed for major overhauls to permit major components to be removed, the ventilation system shall also be designed with regard to disassembly (see 29.4.2).

The Contractor shall also describe and document the ventilation system design in accordance with the document data sheet.

The Contractor shall provide on the information data sheet the key features of the type and performance of the enclosure ventilation system, where applicable, including

— hazardous area external to the enclosure,

— hazardous area at the ventilation inlet,

— type of ventilation, natural or forced,

— nominal flow rate,

— gross enclosure volume,

— number of air changes per hour,

— positive or negative enclosure pressure,

— heat balance by nominal temperature rise across the enclosure,

— the direction of flow through the system,

— the type of ventilation filters, where supplied,

— fan rating,

— fan material,

— fan motor type and quantities,

— fan motor rating(s),

— hazardous area certification of fan assembly(s),

— type of ventilation system dampers,

— the location of gas detectors with respect to the ventilation system,

— the location of fire dampers, and

— the description of the original validation of dilution ventilation.

Where the potential exists for flammable gases, vapours or mists to arise in an enclosure, ventilation and detection equipment and design requirements shall comply with the requirements of 14.4 and 14.5. Details of the explosion protection system, instrumentation and devices that form an integral part of the enclosure systems shall be provided on the information and instrumentation data sheet respectively.

29.2.5 Internal heating

If needed for equipment protection during periods of non-operation, internal space heating shall be supplied. The Contractor shall document the requirement for such equipment due to the nature of their equipment, enclosure design, enclosure location or site conditions in accordance with the document data sheet.

Ventilation system ducting may have automatic or manual dampers that need to be closed during periods of heating.

For extreme climatic conditions, heating may also be required to be supplied into the ventilation system to avoid over-chilling of internal systems during machine operation.

The Contractor shall define on the information data sheet the requirement for heaters, the type, power requirements, quantity and the method of monitoring the status.

29.2.6 Lighting

An appropriate level of local lighting shall be provided in areas where visibility is required for inspection, leak detection, routine maintenance, general access and access for isolation. These shall be illuminated to a minimum intensity of 200 lx.

NOTE EN 12464–1 provides guidance for internal workplace lighting levels.

Walkways shall be illuminated with an intensity of at least 20 lx.

Integral lighting shall comply with the requirements of EN 1837.

Where access is required, main and emergency lighting shall be provided. Light switches, if required, shall be external to the enclosure adjacent to the doorways.

Lighting provided via glass illumination ports may also be used.

29.2.7 Enclosure instrumentation

Where visual checks have to be undertaken on or values have to be recorded from equipment during running conditions and such equipment is located within a non-gas turbine enclosure, provisions shall be provided that allow the visual checks to be undertaken and the values to be recorded without creating hazards.

Regulations may sometimes put responsibility on the Purchaser as owner/operator for the design of the power plant to reduce risk and avoid hazard. A foreseeable hazard is personnel entering a gas turbine enclosure during operation. To eliminate this hazard during normal operation no local instrumentation or panel (that requires supervision) shall be installed in the gas turbine enclosure. Similarly, if local panels are installed in gas turbine enclosures, sufficient signals and alarms shall be available for the operator at the control panel to eliminate the need for gas turbine enclosure entry. Where gas turbine enclosures contain fire or gas detectors or other equipment that require checks/calibration during operation and entry creates a hazardous situation, the required time for these checks should be minimized, enclosure entry shall comply with 14.8, and access boundaries shall be controlled or provisions shall be made to enable such checks and calibration to be undertaken without enclosure entry.

Details of enclosure instrumentation shall be provided on the instrumentation data sheet.

29.2.8 Flooring

Internal floor finishes and stair treads inside an enclosure, if applicable due to the size of the enclosure, shall be slip-free (see also platforms, described in 29.5).

Where applicable, floor areas shall be marked to identify walkways and emergency access routes. Signage shall be provided on all elevated walkways and platforms, indicating emergency escape routes.

29.2.9 Personnel doorway design (including access panels)

Doors, hinged hatchways or bolted access panels providing access into enclosures shall be of sufficient dimensions to allow personnel and materials to be manoeuvred through them without risk of damaging internal lining/coating materials. The opening shall not be less than 1 m^2 in areas where personnel access is intended.

Bolted panels should use captive nuts and have suitable handling facilities for removal, including arrest features if the potential for the panel to fall exists. Panels that interface to hazardous areas shall be earthed.

The requirements to retain any extinguishing medium, and to contain the differential pressure of the ventilation system, along with vermin and weather protection, shall be considered in the sealing design of the enclosure. Maintenance instructions shall include inspection criteria and frequency. Opening/closure of the door while the ventilation system is operating shall not take undue force, even if a warning system exists to alarm of such an event.

● If requested by the Purchaser, door catches shall be fitted with a lockable or pad-lockable mechanism, or use a mechanism interlocked to the fire extinguishing system.

Personnel door catches shall be fitted with internal emergency escape mechanisms to allow opening from the inside that overrides any external door lock. All external doors shall be configured to comply with ISO 21789:2009, 5.13.8.

Light switches, stop buttons, status lights and other interface equipment shall not be installed such that an open door restricts access to or could damage those devices.

The enclosure general arrangement drawing (see 35.4) shall describe the number, size and position of the enclosure doors and opening panels.

29.3 Access and egress

29.3.1 General

General access to and within the enclosure shall be appropriate for the equipment and the maintenance requirement and located and sized accordingly. All access requirements shall comply with the relevant parts of Clause 10 and Clause 14. The enclosure location within the power plant shall be such to permit direct access to the enclosure in an efficient and ergonomically sound manner.

Where possible, given the size and design of the enclosure and the size of the gas turbine, a stairway should be provided to allow access across the gas turbine and prevent tripping hazards and this shall be recorded in the information data sheet.

For safety aspects of access into the gas turbine enclosure refer to 14.8.

Signs warning of the hazards located within the confines of the enclosure(s) shall be posted on all the doors for the areas not normally accessible during operation of the gas turbine.

All walkways and doorways shall be clear and free of obstructions or tripping hazards.

The enclosure general arrangement drawing shall show the access ways and stairways to the enclosure, as applicable.

29.3.2 Enclosure roof access

If access for routine maintenance is required onto the roof of the enclosure (e.g. to ventilation fans), suitable permanent ladders and handrail protection shall be provided. The methods for access to the enclosure roof shall be identified on the information data sheet.

29.4 Maintenance within enclosures

29.4.1 General

In areas of ambient temperatures below −15 °C additional structures shall be supplied to allow heating of the area where maintenance activities take place. In areas of high precipitation it is highly recommended to have an additional structure to allow maintenance activity to be protected from the elements, which is essential for equipment that is maintained without removal from the enclosure. This shall improve the health and safety of maintenance staff during lengthy outages and improve maintenance quality.

The design and layout of the gas turbine package shall be such as to facilitate effective and efficient maintenance. Relevant features and actions shall include the following:

— layout shall allow items to be maintained, removed and installed through doorways, side or roof panels of the enclosure;

— allowance for access by personnel, tools and materials, including provision of access manholes, doors and inspection windows (see 29.3);

— standardization of components, where possible;

— inclusion of all necessary points of isolation, draining, purging, etc.;

— equipment to allow routine maintenance work to be carried out without the provision of scaffolding;

— where low level areas exist within an enclosure which may harbour CO_2, the ventilation system design shall allow these areas to be purged before entry;

— where low level areas exist associated with an enclosure which may harbour residual CO_2 which cannot be fully purged by the ventilation system, confined space procedures shall be adopted during any access;

— enclosures shall be designed such that there are no water collection points;

— gasket and seals inspection and/or replacement during maintenance.

Careful consideration shall be given by the Contractor to the maintainability of the gas turbine package in the design of mechanically fastened joints. Each fastener which has to be loosened, withdrawn or tightened in the course of maintenance shall be accessible for such work, without the need for metal cutting, breaking of concrete or removal of an excessive amount of adjacent equipment. Captive nuts shall be used, where appropriate.

All operational areas within the enclosure, where frequent maintenance access is required and/or carrying tools and equipment, shall be accessible without the need to use vertical ladders. Temporary or permanent ladders or other provisions for infrequent access may be utilized.

Fall protection attachment points shall be included if maintenance of equipment requires activities at more than 2 m (6 ft) above the floor. The safe working load (SWL) shall be locally marked at such points and load angles provided in the mechanical handling documentation supplied in accordance with the document data sheet.

Any enclosure maintenance requirements (e.g. the painting inspection frequency and the repair process) shall be included in the maintenance manual.

29.4.2 Disassembly of enclosure for maintenance

The enclosure shall be designed for dismantling where panels or elements of the structure are disassembled to allow removal of all or part of the equipment for maintenance tasks. The enclosure design shall be capable of planned and unplanned disassembly through the design life without loss of pressure integrity to maintain fire extinguishant concentration in the event of fire system discharge. The design shall be optimized such that

— disassembly minimizes the disruption to ventilation and fire protection systems,

— seal systems between panels shall maintain enclosure pressure integrity despite regular disassembly,

— the removable structure shall contain the minimum of instrumentation and lighting,

— major pipe and cable trays shall be routed clear of removable panels and the lift path of major components,

— any piping or cabling that has to be located on removable panels shall have robust supports and connections accessible for regular dismantling, and

— the structure support frames shall be designed to minimize twisting and distortion during disassembly, lifting and storage of the removable enclosure sections.

29.5 Platforms and access ways

Staircases, galleries, handrails, platforms and other equipment to provide means of access for routine operation, inspection and maintenance purposes, which shall be to support workmen, tools and portions of the power generation package which may be reasonably expected to be placed thereupon during the maintenance and inspection periods, shall be provided. Wherever practicable, staircases rather than ladders shall be used. Permanently-installed access ways to enclosures and, where necessary, access within large enclosures, should be provided with a minimum of 2,1 m headroom and 0,75 m clear width.

Where applicable, means of access shall comply with ISO 14122-1, ISO 14122-2:2001, ISO 14122-3 and ISO 14122-4.

Where standards allow different stair tread or ladder rung spacing, the relationship of adjacent platforms, stairs and ladders shall ensure that the transfer of personnel from one to another does not create unnecessary hazards.

Access ways and maintenance platforms shall include emergency escape facilities, consisting wherever practicable of staircases rather than ladders. Circular spiral stair towers shall not be used. For larger platforms consideration shall be given to having two egress routes.

The Contractor shall identify all instruments, control valves, ventilation systems or other equipment not accessible by normal enclosure access or from permanent ways or platforms inside or outside the enclosure in a specific document. The instruments or equipment shall be identified and the nature and frequency of any inspection or maintenance shall be defined in accordance with the document data sheet.

The enclosure general arrangement drawing shall show all internal access ways, platforms, stairways and ladders.

29.6 Mechanical handling and cranes

29.6.1 General

The enclosure shall incorporate the required features to enable all required maintenance activities to be carried out with minimal disruption to the rest of the power plant. All cranage shall comply with either 29.6.2 or 29.6.3. Tooling for heavy maintenance shall be proof load tested in accordance with regional, national or local regulations and shall bear appropriate signage to declare safe working loads and test date(s). Lifting plans shall be developed and documented in the maintenance manuals covering the handling methods to be used, the centre of gravity of the equipment(s), appropriate dimensions and weights.

Details of internal and external mechanical handling equipment, including any lifting beams, roll out equipment for parts of the gas turbine, special support stands for heavy casings and rotors to be stored during the outage and the frequency of the testing required, shall be detailed in accordance with the document data sheet together with location and safe working loads.

29.6.2 Mobile crane

Where the lifting weights are within the range of a mobile crane, fixed lifting facilities may not be required. The Contractor shall liaise with the Purchaser to ensure that for any equipment that requires a suitably-sized mobile crane, there is a safe access route, secure support for the crane outriggers and that there is sufficient laydown area for removed equipment.

Documentation shall be provided of details for any mobile cranes that are required for installation or maintenance in accordance with the document data sheet.

29.6.3 Fixed installed crane

If required to be integral with the enclosure, the Contractor shall supply fixed lifting facilities to allow for the removal of gas turbines from their base plate for overhaul at works or for overhaul at site.

Documentation shall be provided of details for any fixed cranes that are required for installation or maintenance and the frequency of the testing required in accordance with the document data sheet.

29.7 Laydown and storage

The Contractor shall provide documentation, in accordance with the document data sheet, to identify the laydown and storage requirements for all large or heavy components removed from the gas turbine and its enclosure during site dismantling during maintenance outage, including the enclosure panels and attached ventilation equipment. It is recommended that storage areas shall be designed for access by fixed or mobile lifting equipment plus road transport to move the components to and from the gas turbine to the laydown/storage area. The planning and location of laydown and storage areas shall allow for the planned logical sequence of strip and build of the gas turbine package. The laydown sequence shall be included with the laydown documentation.

29.8 Enclosure fire precautions

Where the risk of fire exists, a system or systems shall be supplied in accordance with the requirements of 14.3 to protect the enclosed equipment(s). The type of extinguishant system proposed by the Contractor including discharge capacity, the number of available discharges and extended discharge capacity, where applicable, shall be identified on the information data sheet.

Unless in an occupied space or otherwise advised by the Purchaser, the fire extinguishant shall be automatically released; an appropriate delay may be necessary after an alarm to warn personnel of the situation. When CO_2 is used as a fire extinguishant, a warning and a delay in accordance with ISO 21789:2009 shall be implemented.

A means shall be provided, in accordance with ISO 21789:2009, to safely isolate the release during maintenance and entry into the enclosure.

A manual actuation system shall be provided. A manual release shall be located externally on the two main opposing sides of an enclosure side and, where present, adjacent to doors(s), access hatch(es) or similar means of access.

● If requested by the Purchaser, fire and gas status lights shall be supplied. These shall be fitted adjacent to access doors on each enclosure that is supplied with a fire system. The Purchaser shall document the functions to be covered by the lights and the colours to be used.

Controls shall be arranged such that following a fire in the enclosure, the extinguishant shall be sustained at an adequate level for a period of time to allow cool-down of the gas turbine to a level below auto-ignition of any flammable fluid that may be present in the enclosure, in accordance with ISO 21789:2009.

A description of the design of the fire protection system, its operation and maintenance, and the extinguishant isolation details shall be described in the operating and maintenance manuals, as applicable. Instrumentation functions to be covered are detailed on the instrumentation data sheet.

A cause and effect diagram and associated documentation shall be provided for fire protection systems (see 35.4).

30 Auxiliary equipment

30.1 Barring equipment

30.1.1 General

The term "barring" in 30.1 is used to describe equipment sometimes described as "turning equipment", which is used for a number of purposes to rotate rotor(s). The extent of the equipment may comprise a single piece of equipment or separate pieces of equipment required to undertake the tasks described in the text that follows. The Contractor shall state the period of rotor barring required after shutdown to prevent rotor distortion on the information data sheet.

The barring equipment shall be designed such that it automatically disengages when barring motive force is removed and automatically reengages when the motive force is applied or speed changes cause engagement or disengagement.

30.1.2 Gas turbine barring systems

30.1.2.1 Barring to prevent distortion

Where applicable to alleviate a rotor distortion problem that may prevent operation, which may be caused by mechanical or thermal effects after shutdown, automatically controlled barring equipment shall be provided for rotating of the entire rotor train for a single-shaft arrangement or for each shaft, as applicable, for a multiple shaft arrangement. The period of rotation shall be sufficient to control this distortion within acceptable limits either before start-up or after shutdown such that the equipment can be started and operated within normal limits.

Rotation of the rotor(s), where required, is to avoid uneven cooling and the resulting distortion which may lead to unacceptable vibration during subsequent running or sticking of the rotor as a consequence of blade-casing contacts, which will prevent further turning or safe re-starting of the gas turbine.

Rotor barring can be provided by a separate motive force, or where a suitable motive force is used for starting, as long as it is used in conjunction with appropriate equipment to control the rotating speed or where the starting ignition speed is utilized for barring. Such turning equipment may also be used for water wash and force cooling to reduce the time that the barring equipment operates.

Details of all barring requirement shall be specified in accordance with the document data sheet.

30.1.2.2 Barring for maintenance

Where necessary for the controlled rotation of rotors for inspections during maintenance activities, barring equipment shall be provided to rotate the equipment in controlled steps applicable to the maintenance task being undertaken. Barring equipment is not necessary where rotors can be rotated manually with or without the hydraulic jacking of rotors at bearing locations.

Barring for inspections would typically be accomplished via access points to the rotors and the use of tooling or a suitable ratchet device that provides the required motive force that allows the rotor(s) to be turned in a controllable manner.

Such equipment may also be used for water wash and force cooling to reduce the time that the barring equipment operates.

Details of all maintenance barring requirement shall be specified in accordance with the document data sheet.

30.1.2.3 Barring during shutdown periods

Where necessary to prevent rotor distortion during shutdown periods by periodic rotation of rotor(s), suitably automatically-controlled rotating equipment shall be supplied. Barring equipment provided to control rotor distortion or for rotation for maintenance activities, where suitable, may be utilized. The period of rotor barring required after shutdown to prevent rotor distortion shall be stated in the information data sheet.

30.1.3 Safety and operational requirements

Any unintended re-engagement of the barring gear or ratchet device during gas turbine operation shall be prohibited by appropriate design or protection measures.

Manual and automatic barring facilities shall comply with health and safety requirements to avoid any unintended turning of the rotor during standstill, which might be specifically dangerous during inspection or maintenance work on the rotor shaft.

Where barring cannot be initiated or where loss of barring during the barring sequence may result in rotor lock, the resulting consequences shall be defined in accordance with the document data sheet including the time after which a restart may be initiated. Where under this condition an extended pre-start rotation period is required, the sequence shall be included in the documentation.

30.2 Starting systems

30.2.1 Types

There are numerous types of gas turbine starting systems available that meet different requirements, as specified by the Purchaser. Since not all types of starter systems are appropriate for a specific gas turbine, clarification of the requirements and the available technical solutions are required during the tender phase.

Starting systems for gas turbines include

— independent electrical motors driven by alternating (AC) or direct (DC) current,

— generators used as starter motors with suitable electrics and electronics,

— hydraulic motors or hydraulic turbines,

— pneumatic motors,

— diesel or gas turbines, and

— steam turbine starts for single-shaft applications.

The Contractor shall provide documentation describing the starting system in accordance with the document data sheet.

30.2.2 General and design requirements

The power generation package starting system shall accelerate the gas turbine from standstill or barring speed to above the self-sustaining speed where the power rating of the gas turbine, from combustion, is large enough to further accelerate the shaft without additional power supply from a starting system.

The start sequence of the gas turbine shall be automatically executed by the control system up to the required operation point after ignition and at a suitable speed or load. Hold points required for turbine and exhaust system fuel purging and gas turbine enclosure purging to mitigate any risks associated with the auto-ignition of hydrocarbons during the start cycle shall be programmed into the start sequence.

Single-shaft gas turbines typically require high starting torques due to the higher moment of inertia than multi-shaft configurations, where typically only the gas generator is rotated during start-up. In all cases, the starting system shall be capable of accelerating all the attached components which are connected to the gas turbine shaft during starting. The Purchaser shall define additional starting and acceleration torque required for generator and steam turbines in accordance with the document data sheet if this equipment is not supplied by the Contractor.

In addition, rotation of the gas turbine may be required without the combustor in operation, for example during start-up for purging or compressor washing or after shutdown of the gas turbine for cooling or stand-by operation.

The capacity of the starting system shall be designed for the expected maximum starting and acceleration torque. Torque converters and hydraulic drives can multiply the applied and breakaway torque required and reduce the starting device power requirements. The Contractor shall specify any utilities or external power supplies that are required for the gas turbine and/or the starting system in accordance with the document data sheet.

The Contractor shall deliver a speed-torque characteristic for the driven gas turbine equipment in accordance with the document data sheet if the starting equipment is not in the scope of delivery of the gas turbine package.

If a form of hydraulic connection, for example with a hydraulic torque converter, is used between the starter motor and the gas turbine, adequate cooling of such a device, where applicable, shall be provided for the worst case conditions within the specified operating range. No additional restrictions shall appear as a result of the application of additional hydraulic equipment for the starting system.

30.2.3 Power supply for starting systems

● The Purchaser shall specify if the gas turbine starting system shall operate without an external grid based AC power supply. The Contractor shall provide sufficient battery capacity in case of a DC-based start-up system and shall ensure the re-charging of the batteries in a reasonable time as specified in the information data sheet. An alternative AC-independent starting system can be implemented by diesel engines, small gas turbines or pneumatic-based solutions.

The electrical starting system shall allow a start of the gas turbine if the voltage level falls below the nominal range but is still within the specified voltage range on the information data sheet.

During black start the values for total harmonic distortion should not exceed the suggested limits of standards IEC 61000-2-2 and IEC 61000-2-4 unless exceeding the electromagnetic compatibility levels are acceptable.

Where applicable, the requirements utilized for the black starting system shall be documented in accordance with the document data sheet.

30.2.4 Start-up restrictions

The Contractor shall specify if the starting system is designed to support one or more gas turbines in a specific power plant. If different gas turbines share one common starting system and restrictions to start more than one gas turbine at the same time apply, the restrictions shall be defined in accordance with the document data sheet. Where it is required to cool-down the starting system equipment before it is possible to start another gas turbine with the same equipment, the requirements shall be documented.

● If requested by the Purchaser for multiple unit installations, each gas turbine package shall have its own dedicated starting device.

Requirements or restrictions for repeated or simultaneous starts shall be specified by the Contractor in accordance with the document data sheet.

30.3 Lube oil systems

30.3.1 General requirements

The lube oil system shall consist at least of suitable equipment for storage, forwarding and returning, filtering, temperature and pressure control, safety and instrumentation equipment and distribution lines to each lube oil consumer of the gas turbine package.

The lubrication system is a vital part of a gas turbine package and needs to have a sound layout, design, installation and maintenance to achieve a good performance and reliability. The lubrication oil system of the gas turbine shall be capable of maintaining the continuous operation of all lube oil consuming parts of the gas turbine without specific carbonization and degradation of the lube oil to maintain the oil quality in the specified range. In addition to the lubrication, the lube oil cools the bearings and transfers the heat back to the reservoir.

The Contractor shall provide an expected oil consumption rate in the information data sheet.

Requirements for the type, quality and maintenance of the lube oil shall be specified in accordance with the document data sheet and documented in detail in the operating manual.

In general, the lube oil system can be combined with other hydraulic systems or work as independent system for lubrication and bearing cooling purposes. If there are separate systems supplied, different types of oil having specific advantages can be used, but the amount of required equipment and parts especially for instrumentation and controls is significantly higher.

The Contractor shall provide documentation describing the lube oil system in accordance with the document data sheet.

30.3.2 Design requirements

30.3.2.1 General

Lube oil is stored in a sufficiently-sized reservoir from where it is forwarded via pumps, coolers, filters and flow control equipment to the different consumers. The oil flows back from the different consumers into the reservoir.

The reservoir can be designed as part of separate auxiliary equipment or might be an integrated part of the base plate of the gas turbine installation. The size of the reservoir shall be designed to fulfil the requirements for the retention time and the working capacity. The retention time is the time allowed for disengagement of air or gas entrained in the oil.

Depending on the type of lube oil and hydraulic oil consumers and the system layout, the reservoir shall have a retention time sufficient to allow a proper de-aeration of the oil and the settling of particles or other type of contamination. If lube oil consumers such as gearboxes and similar equipment are supplied, there is a risk of foam formation which shall not enter the pump suction area and shall not be fed into the lube oil forwarding system. Hydraulic systems, operating on higher pressure levels, are typically sensitive to air contamination of the working fluid. The Contractor shall state the retention time of the lube oil in the reservoir in the information data sheet.

Provisions shall be made for venting of and oil removal from the lube oil system, as required, to put the system into operation or to empty it for inspection and maintenance reasons.

Vents and drains shall be routed back to the oil reservoir provided that entrained oil is suitable for further use.

Where the potential exists for visible or hazardous mists and/or vapours to be emitted from the lube oil tank vent or extraction system, a demister/coalescer shall be fitted to eliminate any potential mists and/or vapours.

30.3.2.2 Lube oil supply system

The lube oil supply system shall have a primary main pump for steady-state operation that can be either shaft or motor driven. The Contractor shall state in the information data sheet the type of drive of primary main pump.

● If requested by the Purchaser, a redundant stand-by pump shall be provided to permit continuous steady-state operation if the primary main pump is unavailable.

An emergency supply system shall be provided in the event that operation of the main pump(s) is compromised while the gas turbine package is operating. This system shall ensure adequate oil supply is provided to permit shutdown of the gas turbine package without any damage to the equipment. The emergency supply system shall be capable of operating independently without utilizing the main pump power source.

Where lube oil is utilized for cooling of components, the emergency system shall have adequate operational time following a gas turbine shutdown to mitigate the risk of components overheating. The gas turbine shall not be continuously operated on the emergency supply system.

Pump suction inlets shall be equipped with strainers of an appropriate mesh size as specified by the pump manufacturer. Non-return valves shall be provided at each pump discharge to avoid reverse oil flow into stand-by or idling pumps. The lube oil supply system shall have pressure regulating valves or other flow control devices as required to ensure the correct oil flow and pressure is provided to each bearing or other oil consumer.

The lube oil supply system wetted surfaces downstream of the lube oil filters shall be made of corrosion-resistant materials. Non-corrosion-resistant materials may be used provided that wetted surfaces are suitably plated or are clean to bare metal and are suitably protected against corrosion when not in use. Where applicable, the procedures required to prevent corrosion when not in use shall be detailed in accordance with the document data sheet.

Prior to the initial introduction of lube oil to bearings or gas turbine seals, the lube oil supply system shall be cleaned and flushed according the procedures defined by the Contractor. Provisions shall be made in the lube oil system for bypassing the bearings (and seals if applicable) of the gas turbine package during oil system flushing operations.

The design of the lube oil system shall be such that trapped air is automatically vented on system start–up.

30.3.2.3 Lube oil return system

Lube oil return connections on the reservoir shall be hydraulically located as far from the pump suction connections as possible to allow an optimal de-aeration of the oil. The required retention time can be achieved by installation of baffle plates in the reservoir and by optimizing the distance between lube oil return and pump suction connections.

On systems without scavenge pumps(s) return lines shall not be filled more than 50 % with oil by volume to allow for proper transfer of any vacuum in the reservoir to the bearings.

● If requested by the Purchaser, sight glasses in the lube oil return lines shall be provided.

30.3.3 Oil reservoirs and storage tanks

The standard tank material should be carbon steel.

● If requested by the Purchaser, a stainless steel tank shall be supplied.

Corrosion inhibitor shall be applied to carbon steel tanks when the tank is not filled during transportation. For more extreme conditions, additional corrosion protection measures may be required.

Lube oil reservoirs can be provided as separate auxiliary equipment or combined with the equipment base plate. The reservoir shall be sealed against the ingress of water and dirt. Top openings shall be raised above the cover plate of the tank.

If an under pressure is required for the oil reservoir and the vacuum is maintained with a vapour extraction fan, the discharge lines shall be routed carefully to avoid any ingression into the gas turbine air inlet, a contamination of equipment or a discharge at a location leading to a health and safety risk. The extraction system shall avoid the release of oil mist into hot sections of the gas turbine.

The oil level in the reservoir shall be indicated by a measurement having at least a low-level alarm in case the oil level drops below the specified minimum operating level. The oil reservoir shall have a drain connection located at the low point of the reservoir or contain other means such as drain pump provisions to allow oil drainage of the storage tank within a reasonable time. Good access to the oil reservoir shall be provided for the sampling of oil probes required for the periodic monitoring of the oil quality.

● If requested by the Purchaser, a manhole or inspection hatch(es), depending on the reservoir size, shall be provided for maintenance and/or inspection purposes.

30.3.4 Temperature control and heating

The lube oil temperature shall stay within the specified temperature range when starting the oil system or operating the gas turbine. Requirements are defined in the information data sheet and need to be maintained during the operation of the gas turbine to keep the oil viscosity in the specified range and to ensure an appropriate cooling of the bearings.

● If requested, temperature controlled, electrical heater(s) shall be supplied by the Contractor. Such heater(s) shall be designed to heat the oil in the reservoir within 24 h from the average minimum ambient temperature seen at site at the lube system to the minimum start-up temperature of the equipment. For more severe conditions, additional measures such as trace heating for the piping and insulation may be required. An oil level interlock shall avoid any operation of the heater at low oil levels.

The design and the arrangement of the heater and the reservoir shall allow an exchange without any collision with other equipment.

A start interlock of the lube oil system shall be provided if the required minimum temperature specified by the Contractor and defined in the information data sheet is not reached.

30.3.5 Coolers

A cooler for the lube oil system shall be provided. The lube oil inlet supply temperature for mineral oil should not exceed 60 °C for extended periods of gas turbine operation at average maximum ambient conditions. Depending on system design and oil type/properties, the cooler(s) shall be sized such that the maximum tank bulk oil temperature shall be below that at which oil degradation will be significant.

● If requested by the Purchaser, a stand-by cooler for redundancy and maintenance purposes shall be supplied coupled with the existing cooler with appropriate valves to enable changeover during gas turbine operation. A switch-over to the stand-by cooler shall be possible without the system delivery pressure dropping to the automatic start setting of the stand-by lube oil pump. Means shall be provided to carefully vent the stand-by cooler before switch-over in order to avoid air being supplied to the bearings.

Features shall be provided to control the lube oil supply temperature to a constant level during variations of load and ambient conditions by controlling the flow of oil through the cooler or controlling the flow of cooling media. The failure mode of the solution shall be to maximize the cooling function.

For a lubricating oil cooler using water media, the pressure level on the oil side shall be higher than on the water side to avoid any water contamination of the lube oil in case of an internal leak at the heat exchanging surfaces. Where the risk of contamination is unacceptable, an additional cooler shall be used to form a closed loop cooling water system serving the lube oil cooler to avoid contamination of the external cooling water.

30.3.6 Filters and contamination

Filters shall be provided to achieve the required quality of the lube oil supply concerning contamination with particles. Redundancy with two full-flow filters shall be provided with valves to switch between filters during operation. A filter switch-over shall be accomplished without the system delivery pressure dropping to the automatic start setting of the stand-by pump. Careful filling and venting of the stand-by filter before switch-over shall be ensured in order to avoid air supplied to the bearings.

The Contractor shall provide recommendations regarding methods and frequency of the lube oil quality assessment and limiting values. Tapping points shall be provided to take lube oil samples after the lube oil filter and in the lower third of the lube oil tank. The methods for classification of oil cleanliness shall comply with either ISO 4406 or ISO 4407.

More demanding requirements may occur if lube oil is used as control oil, if applicable. Such requirements shall be considered for the type, quality and maintenance of the oil and documented as requested in 30.3.1.

The lube oil filter elements shall be selected to meet the efficiency and particle size requirements of the consumers. Dirt carrying capacity and burst pressure shall be included in the selection requirement to achieve planned service intervals.

The design of the filters shall avoid any bypass of unfiltered oil during operation or while filter cartridges are exchanged to prevent contamination of the clean side of the filters.

Since even a little contamination of the lube oil with particles left from shop manufacturing or site assembly can lead to damages or malfunction of the bearings or other hydraulic equipment, it is recommended to flush the lube oil system before hot commissioning and gas turbine operation. The inspection of the cleanliness of the system shall be documented in the operating manual.

30.3.7 Lube oil selection, type and quality

30.3.7.1 General

Mineral or synthetic oils can be used for gas turbine lubrication systems in general. For higher temperature services, synthetic oil is frequently applied. The selection of the right lube oil quality needs to fulfil different needs (lubrication, cooling, actuation, sealing, etc.) depending on the layout of the system.

The type of lube oils acceptable, the specific features required and the reference specification(s) shall be specified by the Contractor in accordance with the document data sheet. Deviant oil types and qualities need the approval of the Contractor before being used for any operation in the lube oil system. Unauthorized deviations can lead to severe equipment damages and warranty issues.

● If requested by the Purchaser, the Contractor shall supply the first fill of approved lube oil.

30.3.7.2 Lube oil properties

Mineral oils for gas turbines are typically of viscosity class ISO VG 32 or ISO VG 46 in accordance with ISO 3448.

Oil samples shall be taken periodically to check the appearance, quality and water content of the lube and hydraulic oil. Appropriate sampling points or equipment shall be provided.

The use of any oil additives or mixing of different oil qualities requires the approval of the Contractor since it may result in an accelerated aging of the oil.

● If requested by the Purchaser, lube oil purification and conditioning equipment for on-line or off-line operation shall be supplied in accordance with the Purchaser's specification.

Lube oil properties shall be defined and, if required, tested based on the following standards:

— Classification: ISO 6743-5;

— Viscosity: ISO 3448, ISO 3104, ISO 2909;

— Density: ISO 3675;

— Flash point: ISO 2592;

— Pour point: ISO 3016;

— Air release: ISO 9120;

— Foaming: ISO 6247;

— Purity: ISO 4406;

— Oxidation stability TOST: ISO 4263-1.

● If requested by the Purchaser, the oil purity shall be specified in accordance with NAS 1638 or SAE AS 4059E.

30.3.8 Use of synthetic oil

Synthetic oils are commonly used for lubrication of aero-derivative gas generators. These oils have improved tolerance to the high temperatures encountered; the use of mineral oils would lead to undesirable deposits being formed.

Normally the synthetic oil system is dedicated to the gas generator, primarily due to the higher cost of synthetic oils.

A high level of system cleanliness is required, particularly if the system also supplies hydraulic oil for the control of gas turbine systems such as inlet guide vanes or bleed valve actuators.

Suitable precautions need to be in place to ensure minimum contact with these fluids. Personnel shall be instructed to use appropriate personnel protection equipment (PPE) to prevent extended periods of skin contact; any vent systems shall incorporate a demister to coalesce vapours.

Requirements for the type, quality, detailed requirements and maintenance of the lube oil shall be documented in the operating manual.

30.3.9 Minimum supervision requirements

At least the following measurements and/or signals shall be provided and integrated in the control system to initiate alarms, start-up interlocks or shutdowns of the gas turbine and to ensure safe operation:

— lube oil temperature in the reservoir;

— lube oil temperature after the cooler;

— lube oil level in the reservoir;

— lube oil supply pressure in the supply line after the filter;

— indication of operation for all lube oil pumps.

A means of maintaining the specified lube oil flow to the bearings under all loads and fault conditions shall be employed to ensure a safe coast down of the gas turbine. All instrumentation listed above shall be shown on the display of the man machine interface (HMI).

30.4 Compressor water wash systems

30.4.1 General

Washing systems are used for gas turbine compressor equipment to reduce the impact of fouling and mechanical–chemical contamination. Fouling and contamination typically appear after a certain period of operation and are attributed to ambient and operational conditions, as well as the quality of the air intake filter equipment. Compressor fouling and contamination reduces gas turbine performance and may change the operational behaviour and the surge margin of the gas turbine and can lead to corrosion pitting of the compressor blades.

The Contractor shall provide an off-line water wash system.

● If requested, the Contractor shall also provide an on-line water wash system.

The Contractor shall provide recommendations for the use of compressor washing systems in relation to mitigation of fouling and corrosion and define operational requirements and procedures, including recommended detergents and anti-freeze agents, for the water wash operation. The recommended washing frequency and duration, wash fluid quantity, and quality shall be defined by the Contractor in accordance with the document data sheet and in detail in the operating manual. The frequency of off-line and on-line washing, where specified, shall be high enough to avoid any significant deposit build-up and sized for a minimum of one wash cycle.

Abrasive compressor cleaning shall not be provided.

Compressor on-line and off-line washing can be provided with the same set of nozzles, if supplied by the Contractor for this purpose.

Visual or physical access to the compressor inlet bell mouth shall be provided, where required, by maintenance inspection.

30.4.2 Off-line systems

Off-line washing of the compressor is much more efficient compared to on-line washing, due to the more intensive application of the washing fluid on the compressor hardware and significantly longer residence times, and shall be provided as the main compressor cleaning process.

Off-line washing of the gas turbine is executed during standstill of the gas turbine after a certain period of cool-down, but requires a slow turning of the rotor with the use of the barring or starting equipment. If a manual control is provided for the off-line washing cycle, the Contractor shall define all required steps and recommendations for the execution of the washing sequence including required safeguards and health and safety requirements.

Appropriate interlocks in the control logic shall be provided to avoid any activation of the compressor off-line cleaning system during gas turbine operation at speed.

Proper drainage of the contaminated water after the cleaning process is required. It shall be handled and disposed of in accordance with regional, national or local regulations. The closing of all associated drains before restart shall be undertaken and covered within the operation manuals.

30.4.3 On-line systems

On-line washing of the compressor is typically less efficient compared to off-line washing cycles due to the impact of the main air flow with the washing media and an evaporation of the washing fluid in the first stages of the compressor. On the other hand, no shutdown of the gas turbine is required and the washing cycle can be performed during gas turbine load operation. On-line water washing systems shall be controlled by the control system without additional manual support besides the activation of the washing cycle, provided the washing equipment is ready (wash detergent and water filled) and connected mechanically and electrically.

Appropriate safeguards shall be provided to avoid any unintended on-line washing cycle while the gas turbine is operating at an inappropriate condition and shall be documented in the operating manual.

The location of the injection nozzles for on-line compressor washing should be designed to achieve an optimal cleaning effect on the first compressor stages without causing blade aerofoil erosion and/or coating loss.

On-line washing systems can have a certain impact on the CO emissions of the gas turbine, which may require a check of regional, national or local regulations or permits by the Purchaser.

30.5 Cooler

30.5.1 Interstage cooling

For external compressor interstage cooling, the entire main air flow of the gas turbine, or parts of it, is extracted and runs through an external heat exchanger to reduce the temperature of the air. This reduces the compression work while increasing the power rating and the fuel consumption of the gas turbine.

The Contractor shall supply all compressor interstage cooling equipment, if required for the specified operation of the gas turbine and required as a mandatory part of the gas turbine design and layout.

For internal compressor interstage cooling, water is injected at one or more locations into the compressor avoiding the disadvantages of the performance penalty of an external interstage cooling system.

Any supply of cooling media and its associated facilities to operate the interstage cooler shall be supplied by the Purchaser. Cooling media requirements such as mass flow, temperature, etc. shall be defined in accordance with the document data sheet.

● If requested by the Purchaser, the Contractor shall supply the secondary cooling system for heat rejection from the interstage cooler, where applicable.

30.5.2 Cooling air coolers

External cooling air coolers are required if the extracted cooling air from a compressor bleed is cooled down by a heat exchanger before it is induced back into the gas turbine for the cooling of hot turbine or combustor parts.

If required for the specified operation of the gas turbine, the Contractor shall supply all cooling equipment required for the specified operation of the gas turbine and required as part of the gas turbine design and layout.

Any supply of cooling media and its associated facilities to operate the cooler shall be supplied by the Purchaser. Cooling media requirements such as mass flow, temperature, etc. shall be specified in accordance with the document data sheet.

30.5.3 Water cooling systems

Cooling water may be used as cooling media for heat exchangers of gas turbine auxiliaries, such as lube oil coolers, generator coolers, cooling of instrumentation and others.

Any supply of cooling media and its associated facilities to operate the cooler shall be supplied by the Purchaser. Cooling media requirements such as mass flow, temperature, etc. shall be specified in accordance with the document data sheet.

If seawater is used for cooling, appropriate materials shall be selected. Such materials may include titanium plates for plate coolers, copper-nickel, brass, or glass reinforced plastic (GRP) for pipework.

30.6 Pipework

30.6.1 Piping design code

All piping, tubing and associated fittings shall be designed to take into account the thermal, physical and chemical stresses to be expected. The material, wall thickness, tensile strength, ductility, corrosion resistance, forming, joining and test methods shall be suitable for the specific media.

Proprietary piping, tubing and fittings considered integral to the core machinery may be designed for safe operation and compliance with appropriate certification bodies in accordance with the Contractor's own design codes or the applicable standards defined as follows.

All pipework and tubing and associated fitting not integral to the core machinery shall comply with at least one or a combination of the following standards:

— ISO 15649, including its normative reference ASME B31.3 and component standards associated with piping/tubing referenced therein, or

— EN 13480-1, including all parts listed in its normative references and associated piping standards, and standards associated with piping/tubing harmonized against the pressure equipment Directive 97/23/EC of the European Parliament, or

— ASME B31.1, including reference to component standards associated with piping/tubing referenced therein.

The pipe/tube and fittings used, where possible, should comply with one of the standards covered in the referenced standards or may make use of proprietary fitting(s) that are approved for use by the Purchaser.

All weldments on pressure retaining parts shall be uniquely identified and preferably referenced to engineering drawings as dictated by the applicable code.

30.6.2 General requirements

The equipment supplied shall include all pipework/tubing, valves, expansion joints, fittings, hangers, supports, bolts and gaskets and any other associated equipment covered in the scope of supply.

30.6.3 Testing and certification

Inspecting and testing shall be conducted in accordance with the standards specified in 30.6.1. The Purchaser shall advise the Contractor on regulations and legislation in accordance with 10.1. Manufacturers of piping systems or pressure vessels shall have implemented a quality assurance system. The quantity of examination and detail of material test data for inspection documents shall be on an appropriate level for the duty of that particular system.

30.6.4 Hydrostatic testing

Hydrostatic testing of each pipe/tube shall be according to the applicable design code.

If water is used for testing of stainless steel pipes it shall have no more than 50 ppm[1)] of chloride; other system-compatible liquids may be used if appropriate.

1) 0,005 vol % (per cent volume fraction) is the equivalent of 50 ppm; ppm is a deprecated unit at ISO.

All traces of water used for testing shall be removed to prevent the chance of bacterial growth or chloride accumulation, which can lead to corrosion or cracking. If the pipe is to be stored after testing and prior to installation, open ends shall be suitably protected to prevent ingress.

30.6.5 Non-destructive examination (NDE)

Appropriate welding standards and NDE weld inspection requirements in accordance with the design code shall be employed. If radiography is to be used, the gamma or X-ray sources shall be selected to suit the thickness of the material to improve the clarity of the image capture.

Personnel shall be qualified to undertake NDE methods and inspections.

30.6.6 Mechanical requirements

All pipework material shall be selected according the underlying piping code to ensure an adequate performance and to meet requirements for strength, flexibility and corrosion resistance, and to ensure the specified design life without failure from erosion or corrosion, unacceptable high stress or other failure mechanisms.

The selection of piping/tubing and associated fittings shall take into account the most onerous conditions of pressure, temperature and loadings, and include allowances for erosion and corrosion that may apply.

All pipework and tubing shall be adequately supported, anchored and guided to prevent undue deflection, stress or strain on any pipe or undue loading to any equipment. Suitable protection methods shall be used to prevent damage from vibration, shipment, operation and maintenance activities, including component removal and replacement.

The Contractor shall carry out pipe stress analyses according the selected code considering the load cases defined therein.

● If requested by the Purchaser, the Contractor shall deliver a pipe stress analysis and documentation in accordance with the document data sheet.

● If requested by the Purchaser, the Contractor shall deliver all the required information for pipe stress analysis by a third party in accordance with the document data sheet.

30.6.7 Joints and connections

Joints in pipework and tubing shall be avoided wherever reasonably possible and where not required for manufacturing, erection, inspection or maintenance reasons. In particular, non-welded joints contain a residual risk for leakages and other failures, especially when operating at high pressure and temperature levels. If expansion joints and metallic hoses are used in the pipework or tubing they shall be designed and installed carefully to achieve the required lifetime and service intervals and to allow the required mechanical or thermal flexibility during operation. Flanged joints shall be kept to a minimum to avoid potential leakage sites, but sufficient flanged joints and make-up pieces shall be provided to facilitate maintenance or to allow access to equipment fitted inside the pipework or tubing such as strainers, instruments, etc.

Flange sealing surfaces shall be free of any scratches, paint or deformation that would prevent proper sealing. The maintenance manual shall identify replacement gaskets required when performing maintenance activities.

Threaded studs or bolts used to hold flanges together shall not be used for mounting accessories, brackets or supporting the pipe itself where any loading may reduce the effectiveness of the flange joint.

Any special equipment for flushing oil systems, such as removable spools at machine interface, shall be included in the Contractor’s scope of supply. Special attention is required for compression fittings used in situations where a failure could result in a safety hazard to personnel, power plant or the environment. Specific instructions for assembly, testing and maintenance of compressions fittings shall be delivered as part of the Contractor's erection and maintenance manuals.

30.6.8 Corrugated flexible metal hoses and hose assemblies

Flexible metal hoses shall comply with ISO 10380 and the following requirements.

— Design and installation shall be such that flexing only occurs in one plane and end fitting allows the installation without residual torsional loads being imposed on the hose in order to achieve maximum life.

— The hose shall not exceed the minimum recommended bend radius in accordance with ISO 10380 or that advised by the supplier.

— Fluid flow velocities shall be minimized to avoid flow induced resonant vibration; consideration shall be given to hoses with a special liner where flow velocity is a concern.

— Where multiple hoses are part of a design, identical hoses shall be employed to the maximum reasonable extent to minimize spare part requirements.

— The installation shall ensure that the hose is not in contact with other piping and support that would cause fretting.

Requirements for hose inspection, life expectancy and replacement shall be identified in the maintenance manual.

The fuel system design shall minimize the use of flexible hose to only those areas that are subject to movement from thermal expansion and vibration.

30.6.9 Non-metallic flexible hoses, hose assemblies and end connections

Non-metallic flexible hoses shall comply with ISO 18752 or an alternative standard acceptable to the Purchaser.

End connections for non-metallic hose shall comply with the requirements of ISO 12151-1 or ISO 12151-2.

30.6.10 Flange connectors

In addition to the requirements for standards associated with the requirements in 30.7, flange connectors in accordance with ISO 6162-1 may be used with all types of piping and tubing assemblies.

In addition to the requirements of the standards listed in 30.6.1, 4 bolt flange connectors in accordance with ISO 6162-1 (SAE J518-1 | SAE J518-2) or related ASME standards may be used.

30.6.11 Insulation of pipework

Piping that can exceed the temperatures defined in ISO 21789:2009 and are located in normally accessible locations shall have thermal insulation so that the allowable surface temperature is not exceeded. Piping in locations having controlled access, or where it becomes hot only occasionally or under fault conditions, can be equipped with "hot surface" warning signs instead of an installation of insulation.

If not specifically specified by the Contractor, the insulation shall be designed in a way to allow dismantling of the pipe insulation for maintenance purposes with a reasonable effort and with the potential for re-use. The design of the insulation shall allow required access to measurement locations or other equipment where required.

Cold water pipes inside buildings shall be insulated where necessary to prevent freezing or condensation dripping onto hot surfaces or electrical equipment.

30.6.12 Trace heating

Trace heating shall be supplied by the Contractor, where required, to ensure the intended operation of the gas turbine equipment under the specified ambient conditions.

30.6.13 Drains

Where normal liquid media drainage flows cannot be used to empty the pipe or tube or where the amount spilled cannot be collected locally, pipework and tubing shall have appropriate provisions to empty a section with a drain nozzle at the lowest point of the system. The slope to the low point and the diameter shall be sufficient to allow gravity flow and to empty the section in a reasonable duration.

Where applicable, an isolating valve shall be provided on each drain line as close as possible to the tapping point. Isolating valves shall be properly secured in their intended position and shall have an appropriate leakage class. Where a drain nozzle is not connected to piping but is open to its surrounding area, additional secured pipe caps are recommended for such drain nozzles.

Manual drains and sampling points shall be easily accessible.

The Contractor shall define the volume, temperature, type and location for drains in accordance with the document data sheet.

If drains are manifolded together, provisions shall be made to prevent backflow.

30.6.14 Vents

Where necessary for maintenance and inspection, manual vents shall be provided at suitable points on all pipework to allow the release of entrapped air and gases in a safe manner and to allow an inerting of the system, where required, for safety reasons.

Pressure relief valves and sampling points shall also be provided, where required, to allow the depressurization and identification of a safe condition of a line after venting or inerting.

Vents for flammable gases shall be terminated to atmosphere in a safe area without an ignition source and shall comply with the safety requirements of ISO 21789:2009, 5.22.2. Vents of toxic and hazardous gases shall be prevented in accordance with ISO 14123-1. Where prevention is not possible, these vents shall comply with the safety requirements of ISO 21789:2009, 5.22.3 to ensure that such emissions cannot reach a toxic or hazardous level that can cause unacceptable exposure.

Vents from systems operating at different pressures shall not be connected. Vent valves which are required to be operated for start-up, shutdown and operation shall be automated.

The Contractor shall define the volume, temperature, type and location for vents in accordance with the document data sheet.

30.6.15 Equipment access

In order to ensure that there is adequate access for the maintenance of equipment associated with piping, the following recommendations should be met.

— Valves, pumps, filters and associated equipment should be installed so that they are easily accessible for *in situ* maintenance or removal for workshop maintenance.

— There should be adequate space at control valves where lifting equipment is required during maintenance or where adequate space is required for *in situ* servicing of the valve internals.

— When thermal insulation is required around a control valve, it should be fitted in such a manner to allow easy removal for maintenance.

— When a pipeline and the associated equipment is heat traced this should be arranged to allow easy removal for maintenance assess.

30.7 Pressure equipment

Pressure equipment, where applicable, shall comply with at least one or a combination of the following requirements.

— Codes and standards in the ASME range for such equipment, typically referenced in ASME B31.1 and ASME B31.3;

— Standards associated with piping/tubing, harmonized against the pressure equipment directive 97/23/EC of the European Parliament, typically defined as standards in the ISO or EN range;

— Regional or national standards or directives specified by the Purchaser as defined in accordance with the document data sheet.

● If requested by the Purchaser, the Contractor shall supply all required documentation to allow a certification of the equipment by regional, national or local authorities in accordance with the document data sheet.

31 Condition monitoring

31.1 General

Condition monitoring is considered to be the acquisition of measurement data existing in the gas turbine control system and the interrogation of the data to determine the condition of the gas turbine, generator and its auxiliary systems. The condition of the equipment is considered to be its physical state that determines the performance or integrity. The key elements are the data acquisition (DA), trend monitoring system (TMS), emission monitoring system (EMS) and vibration monitoring system (VMS), as specified by ISO 19860:2005. As the EMS system is typically required for regulatory reasons and the VMS is an integral system of equipment protection, these are treated separately.

Where selected below, an operating manual for all DA, TMS and VMS systems shall be supplied.

31.2 Vibration monitoring system

31.2.1 Introduction and overview

Vibration requirements associated with the fundamental design of the package item remain within their relevant clauses in this International Standard. Acceptance levels for vibration are specified in 18.2.

31.2.2 On-line vibration analysis systems

● If requested by the Purchaser, the Contractor shall provide, in addition to the monitoring system specified in 26.2.6, install and commission an on-line vibration analysis system. This shall, at least, cover all vibration transducers on the main shaft line outs (i.e. gas turbine, steam turbine, gearbox, generator, exciter, clutch, etc.). Hardware and software to provide access to the system on the gas turbine package shall be provided in the central control room (CCR).

● If requested by the Purchaser, hardware and software to provide access to the system from a terminal room adjacent to the CCR and in two other offices shall be supplied.

● If requested by the Purchaser, communications shall allow and be provided to transmit data to the Purchaser’s data-acquisition system.

● If requested by the Purchaser, communications shall be arranged to enable exchange of data with the Purchaser’s data-acquisition system and allow remote off-site access. All software and hardware to facilitate remote access and connect to the data-acquisition system shall be provided.

31.2.3 Off-line vibration analysis system

● If requested by the Purchaser, an off-line condition monitoring system and archive system shall be offered where required by the Purchaser. The Contractor shall supply the necessary software/hardware and adequate off-line data collectors compatible with the package. Necessary routes and analysis procedures shall be set up by the Contractor to monitor all the appropriate auxiliary equipment.

31.3 Data acquisition and trend monitoring

31.3.1 General

The extent of the scope and requirement for DA and TMS shall be defined by the Purchaser in accordance with the document data sheet.

31.3.2 Scope

The overall DA and TMS package shall be integrated and be able to monitor the following systems as a minimum:

— gas turbines;

— generator;

— key auxiliary systems (fuel supply conditions, oil supply conditions, emission control via steam/water);

— other main drive rotating equipment (e.g. gearbox, clutch), where applicable.

31.3.3 Data-acquisition

The data-acquisition system requirements are specified in 26.12.2.

31.3.4 Trend monitoring system

31.3.4.1 General

● If requested by the Purchaser, a TMS shall be provided. The individual trends to be monitored shall be defined by the Purchaser in accordance with the document data sheet including, but not limited to, the tasks listed in ISO 19860:2005, Clause 5.

● If requested by the Purchaser, the Contractor shall provide the capability and capacity for future data to be trended. The Contractor shall document the limits to this additional capability.

● If requested by the Purchaser, the Contractor shall provide in the control system a specific indicator to identify operation at base load and operation at peak load. This shall permit the Purchaser to trend base load hours.

● If requested by the Purchaser, the control system shall provide the operator with adequate data to determine when compressor fouling has reached a level which requires on-line or off-line washing to be performed.

31.3.4.2 Calculated values

● If requested by the Purchaser, the TMS shall additionally provide the following calculated values for trending, as defined and explained in ISO 2314:2009, Clause 8, for the following selected calculated values:

— TIT or firing temperature;

— compressor and turbine efficiency;

— inlet mass flow.

31.3.4.3 Fault detection by analysis

In addition to the fault detection parameters listed by ISO 19860:2005, Clause 5, Tables 1 to 4, the TMS shall detect the following mandatory faults or conditions:

— high journal and thrust bearing temperatures;

— unacceptable turbine exit temperature spread;

— high combustion dynamics.

● If requested by the Purchaser, and where applicable, the TMS shall collect data and permit analysis to identify the selected following faults:

— unacceptable rotating stall events;

— rotor structural faults by trending of vibration;

— combustor heat shield loss;

— combustor liner or heat shield cracking;

— rotor thermal vibration and stability by trending of vibration through thermal cycles;

— rotor axial vibration;

— combustor burner flashback/tip temperature;

— power output.

32 Installation and commissioning

32.1 Installation

The Contractor shall provide an installation manual with procedures to ensure proper installation in accordance with the contract, design documentation and quality plan. The manual shall include or refer to drawings, instructions, test record, necessary checks and inspection points required for the installation of gas turbine, its auxiliaries and driven equipment. The manual shall also include procedures and instructions for handling and lifting of the supplied equipment to ensure safe installation on site.

The following site installation activities shall be supervised by the Contractor.

— Ensure material delivered to site is properly recorded.

— Equipment and material storage: advise the Purchaser on the correct procedures for storage of materials (to avoid damage associated with ambient conditions).

— Position and align the gas turbine and driven equipment base frames, where applicable.

— Position and level the auxiliary equipment, such as coolers, pump skids, etc., where applicable.

— Install the combustion air intake system: verification of tightness in joints, cleanliness of system and security of filter elements, etc.

— Install the exhaust system: verification of clearances in bellows and alignment of joints, etc.

— Install the fire and gas system.

— Install piping: verification that the installed piping is stress free and installed in compliance to the valid piping standard, including the Contractor's and its sub-supplier's specifications.

— Install electricals: verification that the installation is compliant with the relevant standards and the Contractor's and its sub-supplier's specifications.

— Align the gas turbine and the driven equipment: alignment shall be in compliance with the Contractor's specifications and procedures.

— Perform final inspections of both mechanical and electrical installation.

— Handover to the commissioning team.

— Handover of spare parts and special tools, if applicable (can also be done during commissioning or at Purchaser commercial acceptance).

— Provide as-built installation documentation, i.e. correct drawings, relevant procedures, standards, etc. and assist the Purchaser with input to wider plant drawings.

— Ensure that both best practice and safe practice are being used during installation.

— Ensure that the installation complies with the Contractor's internal quality plan.

Where the Contractor is responsible for installation, the Purchaser shall provide details of any limitations to the installation work on site such as regional or national regulations on working hours, access restrictions, site planning restrictions and noise restrictions in accordance with the document data sheet.

Where the Purchaser is responsible and providing services/personnel for the installation, a technical advisory service shall be made available by the Contractor to support the agreed installation activities. Any site modification to a standard package layout shall consider the impact to both health and safety and maintenance procedures through the complete package life cycle.

As-built installation documentation shall be collated and supplied in accordance with the document data sheet.

32.2 Commissioning

Where the Purchaser is responsible for commissioning, the Contractor shall provide a commissioning manual in the English language with procedures to ensure proper commissioning. The manual shall include or refer to settings, instructions and test records with information required for commissioning of gas turbine, its auxiliaries and driven equipment. The manual shall also include procedures and instructions for handling of media and electrical isolations to ensure safe commissioning on site. The Contractor shall supply technical supervision to support the commissioning.

The following site commissioning activities should normally be supervised by the Contractor:

— energizing of unit control panels;

— component and instrument loop checks;

— system functional checks including verification of cleanliness and tightness;

— logic and system safety checks;

— tuning of starts and load operation during hot commissioning.

Component loop checks shall include operating of valves, motors and heaters.

Safety checks shall, as minimum, include emergency and backup systems, fire extinguishing systems, gas detection systems and unit shutdown system functional verification.

If loop checks have been performed and recorded at the manufacturer's workshop and the same cabling is used on site or a control system with distributed network is used, simplified functional testing is acceptable on site.

Commissioning settings and test records shall include tracking of changes for updating "as-built" documentation.

The Purchaser is responsible for the supply of utilities fuel and the load for the driven equipment when required during the commissioning procedure.

In case of interruptions of the acceptance test or trial run due to circumstances beyond the Contractor's control, the test shall continue after the problem is rectified with no contractual consequence for the Contractor.

If site conditions do not allow some systems checks or operational modes in the commissioning procedure, these tests shall be done after the takeover of the power plant.

As-built commissioning documentation shall be collated and supplied in accordance with the document data sheet.

33 Verification testing

33.1 Scope

The Purchaser and the Contractor shall agree the responsibility for and extent of verification testing during the contract negotiation. Verification tests are the final tests to demonstrate that the power plant can operate reliably and that it meets its contractual performance and environmental requirements.

Testing shall include, as a minimum, the following:

— start-up and shutdown tests to demonstrate that the power plant can safely and reliably start-up and shutdown, verifying, where necessary, contractual start-up requirements;

— grid compliance testing;

— environmental tests, including noise and emissions tests to ensure compliance with contractual requirements;

— contractual performance testing.

The Contractor will provide support to ensure successful grid code compliance testing. However, the test protocol and direction remains the Purchaser's responsibility.

33.2 Reliability test

● If requested by the Purchaser, the Contractor shall carry out a reliability test.

The reliability of the power plant, complete with all ancillary power plant, equipment and services required for a full, safe and efficient operation, shall be proved by starting and operating within the limits of the output specified, and either continuously or intermittently as may be more convenient for the working of the station for the specified period. The programme for the reliability test should be defined by the Purchaser prior to the start of the planned reliability run and the Contractor shall advise variations required to the procedure to suit the Contractor's scope of supply. A reliability test report shall be supplied in accordance with the document data sheet.

The Contractor will be permitted to make any minor adjustments which may be necessary, provided that such adjustments do not in any way interfere with, or prevent the use of, the power plant by the Purchaser, or result in reducing the output, decreasing the efficiency or exceeding the environmental limits.

● If requested, the load profile for the reliability test shall be advised by the Purchaser in accordance with the document data sheet.

The allowable number and consequences of interruptions shall be included in the specification. Interruptions shall include, but not be limited, to the following:

— any deviation from the requested power rating of more than that defined in the contract;

— the failure of power plant to start within the specified time.

If, for reasons beyond the control of the Contractor, the reliability test is interrupted, the test shall resume as if the interruption had not occurred.

33.3 Contractual performance tests

33.3.1 General

Performance tests shall be conducted to demonstrate that the power plant complies with contractual electrical output and heat rate and shall be reported in accordance with the document data sheet.

The contractual performance tests shall be undertaken with operable and calibrated continuous emissions monitoring system (CEMS) equipment (if installed for the gas turbine generator package) or with calibrated emission measurement equipment, which is temporarily installed to ensure that the power plant operates within its contractual limits at all times during the tests. Failure of the CEMS will invalidate a performance test or reliability test.

Simple cycle gas turbines (those supplied and tested without a heat recovery steam generator) and gas turbines supplied separately for a multi-contract combined cycle gas turbine (CCGT) or combined heat and power (CHP) power plant shall be tested in accordance with ISO 2314:2009. Where gas turbines are supplied as part of a CCGT or cogeneration power plant, the power plant should be tested in accordance with ASME PTC 46.

The duration of the CCGT performance tests should be in accordance with ASME PTC 46.

NOTE An alternative standard to use for this test, ISO 18888, is under preparation.

The contractual performance tests should preferably be completed before the reliability test is run, but the sequence shall be included in the specification.

The Contractor shall make available to the Purchaser all unconditioned data relating to the power plant performance recorded during the performance tests in accordance with the document data sheet.

The duration of the performance tests shall be in accordance with ISO 2314:2009 or ASME PTC 22, as applicable.

33.3.2 Test procedure

Where the Contractor is responsible for performance tests, the Contractor shall formulate the testing procedure for carrying out performance tests on the power plant with regard to identifying scope of tests, references and definitions, guiding principles, preparation for tests, operating conditions for tests, instruments and methods of measurements, computation of results and the test reports.

The test scope shall be documented in accordance with the document data sheet. The nature of the tests and programmes, accuracy of measurement, etc. shall be finalized between the Purchaser and the Contractor within three months of the execution of the tests, unless otherwise defined by the Purchaser in accordance with the document data sheet.

The allowable number and consequences of interruptions shall be included in the test. Interruptions shall include, but not be limited to

— any deviation from the requested power rating of more than that defined in the contract, and

— the failure of power plant to start within the specified time.

If, for reasons beyond the control of the Contractor, the test is interrupted, the test shall resume as if the interruption had not occurred.

33.3.3 Measurement uncertainty

A pre-test uncertainty analysis shall be carried out to confirm that the selected instruments and test design provide test uncertainties on corrected heat rate and power no greater than those in accordance with 5.3. A post-test uncertainty analysis shall also be carried out to validate the test, the results of which shall be included in the test report. The details and results of the pre-test uncertainty analyses shall be included in the test procedure.

33.3.4 Tolerances

The value and method of use of tolerances for test values shall be defined by the Purchaser in accordance with the document data sheet.

33.3.5 Correction curves

The allowable correction curves shall comply with the performance test standard.

The performance test procedure shall describe precisely how the correction factors shall be used to correct the as-tested performance.

As an alternative to traditional correction curves, a performance prediction computer model may be used as the basis for predicting contractual performance at the specified conditions based on measured performance. The method of making such performance predictions shall be included in the performance test procedure.

33.3.6 Performance degradation

While it is recognized that gas turbine performance degrades over time, the application of degradation is a contractual issue and degradation curves shall be supplied in accordance with the document data sheet. See also 5.1.1 for the definition of “new and clean”.

33.3.7 ISO TIT values

● If requested by the Purchaser, the ISO TIT value shall be calculated using the methodology provided in ISO 2314:2009 provided the gas turbine drives a dedicated generator as per multi-shaft combined cycle layout and for single-shaft combined cycle gas turbine layout that employs a clutch. In such cases, the ISO TIT value shall be provided for rated design conditions and validated during acceptance testing. This test parameter will provide high confidence for the combined cycle acceptance testing that the gas turbine is operating at design conditions and that test results are valid. A version of the ISO 2314:2009 TIT shall be provided for both combustors of a sequential combustion gas turbine. It shall also be provided for and tested by Contractors that usually quote turbine rotor inlet temperatures. Details shall be provided in accordance with the document data sheet.

33.4 Noise tests

The requirements for noise tests shall comply with 7.3.

Where the requirement for near field noise measurements is specified in 7.3, such tests should be undertaken at

— MCR, and

— during the transient operation and single events such as the operation of blow offs and vents where high noise levels are generated.

The measurement equipment shall comply with IEC 61672-1. The results of the tests shall be fully reported together with operating conditions of the equipment, meteorological conditions, noise measurements, instrument locations and instrument details.

Any increase in noise levels above that allowed in the contract shall be rectified and repeat tests shall then be carried out to demonstrate that the remedial works have been successful in eliminating the noise problem.

33.5 Emissions test

● If requested by the Purchaser, the Contractor shall implement an emission test using either CEMS equipment (if installed for the gas turbine generator package) or with calibrated emission measurement equipment, which is temporarily installed to ensure that the power plant operates within its contractual emission limits. Test results shall be detailed in accordance with the document data sheet.

● If requested by the Purchaser, a predictive emissions monitoring system (PEMS) may be employed. Any such PEMS system shall have data supplied to prove its accuracy over the full operational range. Results shall be detailed in accordance with the document data sheet.

34 Design life

For details of the design life for gas turbine core components or modules either subject to replacement at planned maintenance intervals or not refer to 18.1.

The minimum design life of the power generation package equipment, components or modules outside the scope of the gas turbine core (see 18.1) not subject to planned replacement shall be 100 000 h based on fired hours running of the gas turbine.

The minimum design life for the exhaust flexible shall be 50 000 h at MCR and 1 250 fired starts.

Rotating equipment subject to gas turbine start-up loads shall be designed for 5 000 starts.

The design shall take into account additional imposed loads due to environmental loads, including wind, rain, snow, temperature and foreseeable seismic activity as specified by the Purchaser, and loads incurred during erection, installation and maintenance executed in according with the Contractor's specification.

Life for civil design and foundation requirements shall comply with 22.1.

35 Technical information and documents

35.1 General

All instructions shall be prepared in line with the principles, content and presentation requirements of IEC 82079-1 unless otherwise stated herein.

Data sheets form an integral part of this International Standard and shall be completed as described in the Scope (Clause 1) and Annex A. The Purchaser shall initially complete the data sheets for the tender, defining the Purchaser's requirements. The Contractor shall respond by completing applicable data sheets and supplying the documentation indicated for the tender stage and subsequent documentation required for the subsequent contract stages.

The detailed information, option requirements, instrumentation and documentation requirements applicable to this International Standard are covered either indirectly or explicitly in clauses of this document as referenced in the master data sheet index. A description of the types of data sheets and their usage is defined in Annex A.

Each document, including drawings and 3D models issued by the Purchaser or Contractor, shall have a unique identity.

The name of the publisher of the document and the publisher's unique document number, the revision index and date of revision shall be shown.

Drawings shall follow the principles included in ISO 128-1.

35.2 Instructions for use

35.2.1 General

Instructions for use shall comply with ISO 21789:2009, Clause 7.

Units of measurement, language and the power plant identification system are required as described in Clause 15.

Instructions and documentations for packing and transportation are required as described in Clause 17.

Instructions for installation and commissioning are required as described in Clause 32 and 26.13.

Instructions for operation are required as described in 11.8.

Instructions for maintenance are required as described in 28.10.

35.2.2 Document format

The acceptable format(s) for documentation is (are) shown on the data sheet index.

Where paper or transparencies type media is used the document size(s) shall be selected from the data sheet index for both documentation and drawing.

Where electronic documentation is used this shall be in portable document format (PDF) for normal documents or drawings or the model format(s) specified.

35.3 Document submission stages and responsibility

The Purchaser/Contractor shall in the document data sheet identify the submission stages and responsibility for the required documentation.

35.4 General documentation

Drawings, diagrams, manuals, lists, interface details, foundation loading and data sheets shall be supplied covering the following:

— documented description of all major systems (tender stage);

— general arrangement drawing of site layout;

— general arrangement/assembly drawing(s) covering elevations and plan of the gas turbine package and all systems/key auxiliary assemblies showing the major dimensions and any electrical or mechanical interface details including elevations and plan;

— drawings showing the outline of the gas turbine core showing supports, borescope access points, balance planes, inspection points/hatches, fuel manifolds and any other major items of equipment associated with the gas turbine core;

— piping and instrumentation diagram/drawing (P&ID) system diagrams for all applicable systems;

— operating manuals for all systems;

— maintenance manuals for all systems;

— installation manuals for all systems;

— commissioning manuals for all systems;

— alarm and trip effect information for all applicable systems;

— supplier data sheets of all major items of equipment, controls and instrumentation;

— single line electrical diagrams/wiring diagrams;

— earthing diagrams;

— electrical cable lists;

— mechanical and electric equipment interface details, where applicable and where not covered on general arrangement drawings;

— imposed foundations load for all applicable items of equipment and any additional loading from worst case environment loads;

— equipment mechanical handling loads during construction/installation;

— equipment installation and erection documentation;

— cause and effect diagrams for all applicable systems.

Annex A
(normative)

Use of data sheet requirements and options

A.1 General

As specified in the Scope (Clause 1), data sheets in this annex are provided for defining requirements and exchanging information between the Purchaser and Contractor, in addition to the requirements directly defined in Clauses 4 through 35.

The data sheets are available to download in PDF and Excel format from the following link:

http://standards.iso.org/iso/19859

The Purchaser shall fill in the data sheets for the tender and forward them to the Contractor. The Contractor shall respond by completing the applicable data sheets for their tender.

Four types of data sheets are provided as follows:

— Information data sheet — For the definition of specific values for equipment, conditions, ratings;

— Options data sheet — For the definition of options and associated information;

— Instrumentation data sheet — For the definition and selection of instrumentation;

— Document data sheet — For the identification of documentation requirements and the stage for release.

The data sheets shall be actioned as described in A.2 to A.5.

A.2 Information data sheet

The information data sheet shall be completed by the Purchaser or Contractor, as applicable, against the referenced clause of this International Standard where relevant to the scope of supply.

Where columns for entries by the Purchaser and Contractor are empty, and therefore do not indicate which column should be completed, a hash character "#" has been included in the applicable column. The associated blank column space can be used for a response to the input for instance where compliance may be a problem.

A.3 Options data sheet

A bullet ● at the beginning of a paragraph in the text of this International Standard indicates an optional requirement which, if requested (relevant to the scope of supply), is selected on the options data sheet "Scope" column at the tender stage. A "Y" shall be entered in the "Scope" column indicating the option is required. If an option is not required a "N" shall be entered in the "Scope" column. Where the Purchaser requires a variation to the requirement, this shall be documented in the "Standard Options" column. The Contractor's agreement or disagreement with this requirement is indicated in the "Compliance" column along with any applicable comments in the "Response" column. Where the option selected includes an information or documentation requirement, this shall be provided on the information or document data sheet as applicable.

Where the Purchaser documents a variation to the defined options, it should be noted that such a variation is likely to attract additional costs and extend the delivery time.

A.4 Instrumentation data sheet

Instrumentation supplied and its control, annunciation, display and type are indicated by the Purchaser or Contractor against the referenced clause of this International Standard where relevant to the scope of supply by the use of the relevant selection key.

A.5 Document data sheet

The document data sheet complement the data sheets described in A.2 to A.4 and define what documents are required at each of the stages of the procurement process (tender, contract, final).

Documents shall be supplied by the Purchaser or Contractor as described against the applicable referenced clause of this International Standard where relevant to the scope of supply. Where documentation is required as part of a selected option this is indicated by including (Option) at the end of the text.

For documents where a requirement may also be required, the ability is provided in the text for an alternative by the use of "unless otherwise". Where an entry on the document data sheet is used for this purpose, the word (Variant) is included at the end of the text.

Documents relating to a topic can be combined into a single document with references to the applicable clauses of this International Standard against which the documentation is required.

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

[3] ISO 7919-2, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

[4] ISO 7919-3, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 3: Coupled industrial machines*

[5] ISO 9001, *Quality management systems — Requirements*

[6] ISO 9613-2, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*

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[9] ISO 11124-1, *Preparation of steel substrates before application of paints and related products — Specifications for metallic blast-cleaning abrasives — Part 1: General introduction and classification*

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[11] ISO 14726, *Ships and marine technology — Identification colours for the content of piping systems*

[12] ISO 17776, *Petroleum and natural gas industries - Offshore production installations — Guidelines on tools and techniques for hazard identification and risk*

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[17] ASME PTC 46, *Performance Test Code on Overall Plant Performance*

[18] NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

[19] SAE J518-1, *Hydraulic Flanged Tube, Pipe, and Hose Connections, 4-Screw Flange Connection Part 1: 3.5 MPa to 35 MPa (Code 61)*

[20] SAE J518-2, *Hydraulic Flanged Tube, Pipe, and Hose Connections, 4-Screw Flange Connection Part 2: 42 MPa (Code 62)*

[21] Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

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