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Gas turbines — Procurement —

Part 3: Design requirements

Turbines à gaz — Spécifications pour l'acquisition —

Partie 3: Exigences de conception

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 3977-3 was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

This second edition cancels and replaces the first edition (ISO 3977-3:2002), of which it constitutes a technical revision.

ISO 3977 consists of the following parts, under the general title *Gas turbines — Procurement*:

— *Part 1: General introduction and definitions*

— *Part 2: Standard reference conditions and ratings*

— *Part 3: Design requirements*

— *Part 4: Fuels and environment*

— *Part 5: Applications for petroleum and natural gas industries*

— *Part 7: Technical information*

— *Part 8: Inspection, testing, installation and commissioning*

— *Part 9: Reliability, availability, maintainability and safety*

Gas turbines — Procurement —

Part 3: Design requirements

1 Scope

This part of ISO 3977 covers the design requirements for the procurement of all applications of gas turbines and gas turbine systems, including gas turbines for combined cycle systems and their auxiliaries, by a purchaser from a packager. It also provides assistance and technical information to be used in the procurement.

It is not intended to deal with local or national legislative requirements with which the installation may be required to conform.

This part of ISO 3977 is applicable to simple-cycle, combined-cycle and regenerative-cycle gas turbines working in open systems. It is not applicable to gas turbines used to propel aircraft, road construction and earth moving machines, agricultural and industrial types of tractors and road vehicles.

In cases of gas turbines using special heat sources (for example, chemical process, nuclear reactors, furnace for a super-charged boiler), this part of ISO 3977 provides a basis.

The relevant parts of ISO 3977 are applicable to closed and semi-closed systems.

NOTE Additional requirements for special gas turbine applications are described in ISO 3977-5.

2 Normative references

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

NOTE In cases where there are no International Standards available, national standards as shown in Annex B may be used as guidelines with the mutual agreement of the purchaser and packager.

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 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 3977-1:1997, *Gas turbines — Procurement — Part 1: General introduction and definitions*

ISO 3977-2:1997, *Gas turbines — Procurement — Part 2: Standard reference conditions and ratings*

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

ISO 3977-7:2002, *Gas turbines — Procurement — Part 7: Technical information*

ISO 3977-8:2002, *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 7919-1:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines*

ISO 7919-2:2001, *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*

ISO 7919-4:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 4: Gas turbine sets*

ISO 10441:1999, *Petroleum and natural gas industries — Flexible couplings for mechanical power transmission — Special purpose applications*

ISO 10442:2002, *Petroleum, chemical and gas service industries — Packaged, integrally geared centrifugal air compressors*

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

ISO 10814:1996, *Mechanical vibration — Susceptibility and sensitivity of machines to unbalance*

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

ISO 10816-2:2001, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Land-based steam turbine generator sets in excess of 50 MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min*

ISO 10816-4:1998, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 4: Gas turbine driven sets excluding aircraft derivatives*

ISO 11086:1996, *Gas turbines — Vocabulary*

ISO 11042-1:1996, *Gas turbines — Exhaust gas emission — Part 1: Measurement and evaluation*

ISO 11042-2:1996, *Gas turbines — Exhaust gas emission — Part 2: Automated emission monitoring*

ISO 13691:2001, *Petroleum and natural gas industries — High-speed special-purpose gear units*

ISO 13709:2003, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 15649:2001, *Petroleum and natural gas industries — Piping*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

ASME, *Boiler and Pressure Vessel Code Section IX*

ASTM A 194, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength*

NACE MR 0175/ISO 15156, *Petroleum and natural gas industries — Materials for use in H_2S containing environments in oil and gas production*

3 Terms and definitions

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

3.1
aeroderivative
aircraft propulsion gas generator adapted to drive mechanical, electrical or marine propulsion equipment

3.2
anti-icing system
system to heat up the air entering the air filter or compressor to prevent the formation of frost or ice on the filters or compressor inlet

3.3
area classification
classification of an area according to differing degrees of probability with which concentrations of flammable gases or vapours may arise

3.4
atomizing air
compressed air used to aid formation of finely dispersed spray from liquid fuel nozzles

3.5
bi-fuel operation
simultaneous operation of the gas turbine on two dissimilar fuels (not pre-mixed), such as gas and distillate

3.6
back draft damper
arrangement with excentrically pivoted vane(s) designed to close and seat when through flow is reversed

NOTE Their function is to prevent backflow through a unit on standby in a spared installation. The dampers are installed in the fan discharge.

3.7
coalescing element
arrangement of fibrous material with special properties which accumulates, entraps and drains moisture from a main air stream

3.8
column mounting
arrangement whereby a baseplate is mounted at discrete points

3.9
cooling period
period in time immediately following the shutdown of the gas turbine during which precautions have to be taken to protect the unit

EXAMPLE During lubrication and turning.

3.10
critical speed
rotating speed which corresponds to resonant frequencies of the system and of the forcing phenomena

NOTE If the frequency of any harmonic component of a periodic forcing phenomenon is equal to, or approximates the frequency of any mode of rotor vibration, a condition of resonance may exist. If resonance exists at a finite speed, that speed is called a critical speed.

3.11
driven unit
components of plant being driven by the gas turbine

EXAMPLES Generator, pump or compressor.

3.12
dual fuel system
system which allows the gas turbine to operate on two dissimilar fuels separately

3.13
electrical and mechanical run out
total indicated reading from an inductive gap measuring transducer targeted on the rotor's designated vibration monitoring track when the rotor is rotating at very low speed (slow roll) in the gas turbine or is turned on V blocks supported on its bearing surface

NOTE This will include mechanical (eccentricity, ovality or any surface irregularity) and electrical (residual magnetism and non-uniformity of the electrical properties of the rotor surface material) effects.

3.14
enclosure
housing over the gas turbine usually designed for acoustic cooling and/or fire retention purposes

NOTE It also may be used to segregate gas turbine cooling and a hazardous area.

3.15
emergency shutdown
immediate manually or automatically initiated shutdown of the gas turbine to prevent/minimize hazards, danger to personnel or impending damage

3.16
filter stage
section of a filter system which is designed to remove specific site contaminants at a prescribed efficiency and pressure drop

NOTE A stage may be a specific media, an inertial separator, a mist eliminator, or a self-cleaning section. Multistage filters are combinations of the various filter stages.

3.17
foreign object damage
damage to a gas turbine component from the passage of an object not belonging to the gas turbine

3.18
high-pressure spool
compressor and turbine rotor assembly of high-pressure stages when driven by a turbine independent of the low-pressure stages

3.19
hot gas path temperatures
temperatures of the combustion gases, anywhere in the hot section of the gas turbine, normally measured at a point downstream of the combustion system

3.20
inertial mist eliminator
arrangement of vertical chord-wise curved louvres with entrainment lips on the pressure side trailing edge which separates by inertia effect, entraps and drains moisture from a main air stream

3.21
inlet plenum
compartment immediately upstream of the compressor inlet

NOTE This is more commonly applicable to aeroderivative gas turbines which require an undisturbed flow into the compressor.

3.22
landfill gas operation
operation of the gas turbine on a fuel gas which has been produced by a natural decomposition process of waste material

3.23
loading
application of load to the gas turbine via the driven unit, generator, pump or compressor

3.24
low-pressure spool
compressor and turbine rotor assembly of low-pressure stages when driven by a turbine independent of the high-pressure stages

3.25
lower explosion level
concentration of flammable gas or vapour in air, below which the gas atmosphere is not explosive

3.26
mal-synchronization
connection of an alternator to an electrical system when the phase of the alternator voltage does not match that of the system

3.27
maximum continuous speed
⟨for generator drive applications⟩ speed equal to the specified upper system frequency

3.28
maximum continuous speed
⟨for mechanical drive applications⟩ speed equal to the 105 % of the highest speed required by any of the driven machine specified operating conditions

3.29
multiplane dynamic balancing
balancing by spinning a rotor on bearings and applying corrections at balancing planes along its length

3.30
net specific energy
minimum energy within a fuel of given constant constituents without latent heat from condensation of water resulting from combustion

NOTE 1 Expressed in J/m^3 [15 °C and 101,3 kPa (1,013 25 bar)] or J/kg.

NOTE 2 Net specific energy is also known as net calorific value or lower heating value.

3.31
off-line compressor washing
procedure for cleaning the compressor by soaking in a cleaning fluid whilst slowly turning the gas turbine

3.32
on-line compressor washing
procedure for cleaning the compressor by injecting cleaning fluid into the compressor inlet with the gas turbine loaded

3.33
operating speed range
range from the minimum to maximum continuous speed defined by the requirements of the application, as limited by the gas turbine design

3.34
packager
supplier having responsibility for coordinating the technical aspects of the equipment, and all auxiliary systems included in the scope of the supply

NOTE This includes responsibility for such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping and testing of components.

3.35
potential maximum power
expected power capability when the gas turbine is operated at maximum allowable firing temperature, rated speed, or other limiting conditions as defined by the manufacturer and within the range of specified site values

3.36
process controller
control of a process variable, such as driven unit pump suction pressure, via the control of the gas turbine speed

3.37
quill shafts
shaft of reduced section designed to be torsionally and laterally flexible

NOTE It may also be designed to fail when the drive torque exceeds a predetermined value.

3.38
reset
action, usually manual, to allow the control system to prepare for a further start attempt following a fault shutdown or unsuccessful start condition

3.39
residual magnetism
magnetism inducted into a magnetic material by exposure to magnetic fields during manufacture or service

3.40
ribbon cable wiring
multiple conductors arranged in parallel, insulated from each other in a flat form

3.41
rotor blade
blade fitted to the rotor (sometimes referred to as a bucket) as opposed to the blades fitted to the stator (referred to as blades, stator blades or nozzles)

3.42
rotor dynamics
analysis of the motion of a rotor-bearing support system with respect to lateral and torsional perturbations

3.43
safe area
area in which explosive atmospheres are expected to be present in low quantities so that special precautions for the ignition sources are not necessary

3.44
self-sustaining speed
minimum speed of rotation of the gas turbine's rotor under normal operation in which no external power supplied by a starting device is required to maintain steady-state operation

3.45
service life
duration that a component will fulfil its function under operating conditions

3.46
shear type coupling
shear pin
coupling which drives through a bolt(s) in shear which has (have) a reduced cross section, in line with the coupling flange to flange interface, which is designed to fail when the drive torque exceeds a predetermined value

3.47
shutdown, automatic
stopping of the gas turbine which is fully executed by the control system from a single operator action

NOTE This type of stopping normally will not lock out further start attempts, and will not require reset action.

3.48
shutdown, manual
stopping of the gas turbine which is manually initiated or controlled at each step

NOTE This type of stopping normally will not lock out further start attempts, and will not require reset action.

3.49
shutdown, semi-automatic
shutdown of the gas turbine which is in part manually initiated or controlled

NOTE This type of shutdown normally will not lock out further start attempts, and will not require reset action.

3.50
starting
action of starting the gas turbine, through all parts of the package start cycle

3.51
stranded conductors
cable having a multiplicity of wires making up the core conductor

3.52
un-interruptible power supply
power supply that is maintained for a stated period under main grid failure conditions

3.53
Wobbe index
WI
heating value of the fuel divided by the square root of the specific gravity (relative to air)

[ISO 3977-4]

NOTE 1 The heat input from the gas fuel through the governor fuel valve under defined conditions is directly proportional to the Wobbe index.

NOTE 2 Alternative definitions for Wobbe index exist and the way of defining the Wobbe index for gases should be agreed upon between the purchaser and packager.

3.54
Zone I/Div I
area in which an explosive atmosphere is likely to occur in normal operation

3.55
Zone II/Div II
area in which an explosive atmosphere is not likely to occur in normal operation and, if it occurs, it will only exist for a short time

4 Basic requirements

4.1 General

This clause covers the basic requirements for the procurement of gas turbines and gas turbine systems for all applications, including combined-cycle systems, and their auxiliaries by a purchaser from a packager. Additional requirements for special gas turbine applications are described in ISO 3799-5. It provides assistance and technical information to be used in the procurement.

4.2 Site-specific conditions

4.2.1 Site conditions

The purchaser shall furnish accurate site condition data to the packager on data sheets such as those shown in Annex A. The purchaser shall specify whether the package is intended for indoor or outdoor installation.

4.2.2 Site operating point

The purchaser shall specify the site-specific operating point(s) on the data sheets (similar to those included in Annex A, Table A.1). Unless otherwise specified, the gas turbine shall be designed to provide site rated power with no negative tolerance, at the heat rate tolerance quoted.

4.2.3 Preliminary design review

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

4.3 Operational requirements

4.3.1 Operational criteria

The package shall operate on the test stand and/or on its permanent foundation within the specified acceptance criteria.

The gas turbine package shall be mechanically designed for continuous service at design power output. All components of the package shall be designed for service at potential maximum power corresponding to the peak load or low ambient temperature characteristics, i.e. components such as couplings, gears and driven machines shall not impose a mechanical limit on the output from the unit.

When a unit operates intermittently at a rating higher than peak rating, it may have components rated at higher power levels or with shorter life expectancy.

The purchaser shall specify the available utility supplies on the data sheets. The packager shall provide the required utility requirements on the data sheets (see Annex A, Table A.1).

4.3.2 Temperature and speed limits

Within the packager's allowable temperature range, the following requirements shall be satisfied.

Equipment shall be run without damage or need for inspection at the overspeed resulting from the instantaneous loss of maximum potential load with the speed control system fully functional.

Equipment shall not fail at the overspeed resulting from the following:

a) instantaneous loss of maximum potential load with the fuel control valve failed in the full open position;

b) instantaneous loss of load resulting from failure of the main drive coupling (e.g. shear pin coupling).

The packager shall advise the purchaser of any inspection that would be required if such overspeed conditions occur.

Attention is drawn to the necessity of also ensuring that all coupled equipment (including auxiliaries, etc., electrically, mechanically or hydraulically coupled) will withstand the corresponding overspeed.

4.3.3 Starting requirements

The purchaser shall define any operating requirements which impact the start cycle sequence or duration.

The package design shall permit immediate restarting from any condition (i.e. hot starts or cold starts). Any restrictions shall be defined in the proposal. Any turning device necessary to meet this requirement shall be provided by the manufacturer (see 6.2).

4.3.4 Transient requirements

Operational stability under transient load conditions shall meet the requirements as specified by the purchaser. These requirements should be clearly defined by a relationship of load, speed and time parameters.

4.3.5 Control requirements

The package control system designed by the packager shall provide for sequenced startup, stable operation, warning of abnormal conditions, monitoring of operation, and shutdowns of the package in the event of impending damage to the unit (see Clause 6).

4.3.6 Instrumentation and communication

The purchaser shall specify requirements for instrumentation, data acquisition, data transmission and system interface with the total facility (see Clause 6).

4.3.7 Fuels

The fuel system shall be operable with the normal fuel or any alternative or starting fuel specified in ISO 3977-4. The packager shall advise the purchaser of the effects of the fuel(s) on gas turbine package operation and equipment life.

4.3.8 Exhaust emissions

The exhaust emissions from gas turbines (mainly NO_x, CO, UHC, SO_x, smoke and particulates) depend to a large extent on the fuels used and the operating conditions of the gas turbine. Therefore the conditions for the specified exhaust emission limits to be met shall be agreed between the purchaser and packager.

If not otherwise specified, the limit values required by national legislation valid in the country where the gas turbine operates shall be met. Where no national legislation exists, the limit values shall be agreed between the purchaser and packager.

In all cases, the exhaust emission measurement shall be carried out according to ISO 11042-1 and ISO 11042-2. The exhaust emissions control technique shall be specified by the purchaser (see 4.6.2 and 5.2.8.5).

4.3.9 Noise emissions

If sound control is specified, the requirements of ISO 3977-4 shall apply. Any special near field or far field or neighbourhood sound restrictions that are applicable shall be specified by the purchaser in the data sheets.

The permitted near-field, far-field and inside-buildings noise levels shall be provided by the purchaser.

The noise emission measurement of the gas turbine and gas turbine package shall be carried out according to ISO 10494.

4.4 Service requirements

4.4.1 Design life

Unless otherwise specified, the gas turbine packages covered by this part of ISO 3799 shall be designed and constructed by the packager for the following minimum design criteria (corresponding to class D, range IV, defined in ISO 3977-2:1997):

— a design life of 20 years or 100 000 operating hours, whichever occurs first;

— a hot gas path inspection interval of 8 000 h;

— a time between major overhauls of 24 000 h.

Shorter inspection and major overhaul intervals may result from

— operation with fuels other than natural gas,

— applications with water or steam injection,

— operating regimes other than class D, range IV, or

— special designs.

It is the packager's responsibility to identify in his proposal any special equipment and maintenance procedures necessary to achieve the aforesaid life and service intervals.

4.4.2 Responsibility for the unit

The packager shall be responsible for the gas turbine package performance and mechanical integrity, provided the package is operated and maintained as per the packager's instructions.

4.4.3 Inspection schedule

Recommended inspections, normal maintenance and major overhaul intervals shall be stated in the packager's proposal.

All equipment shall be suitable for periods out of operation up to a minimum of 4 weeks, under specified site conditions, without requiring any special maintenance procedures.

4.4.4 Inspection and maintenance access

The package shall be designed for ease in servicing and to provide adequate clearances necessary to perform all maintenance to be done between hot gas path inspection. Special tools and procedures shall be stated in the packager's proposal.

Provision shall be made for the complete inspection of all rotating gas path and combustion system components, using borescopes or other devices, without major disassembly of the gas turbine. The packager shall provide details of the procedures and any special equipment to be used.

4.4.5 Power train maintainability

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

4.5 Rotating equipment requirements

4.5.1 Coupling

Couplings shall be sized for maximum continuous torque, based on the potential maximum power capability that can be delivered.

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

The couplings shall be dynamically balanced on an individual component basis and then assembled into a completed coupling which is also dynamically balanced as an assembly.

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

Coupling spacer length shall allow removal and replacement of bearings and seals without disturbing the main equipment casings. Where this is impractical, the removal of components shall be kept to a minimum and the driven equipment should not be disturbed.

When specified, the main load couplings shall conform to ISO 10441. The coupling make, type and mounting arrangements shall be agreed by the purchaser and packager. A spacer-type coupling shall be provided unless otherwise specified.

4.5.2 Auxiliary gears

The gas turbine driver 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 an agreed standard, and shall be rated for at least 110 % of the maximum power transmitted.

4.5.3 Load gears

Unless otherwise specified, the load gear design, testing and application shall comply with ISO 13691 and the purchaser's specifications. Pertinent gear loading data shall be designated by the purchaser.

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

The minimum load shall also be considered in the design of the load gear, taking into account critical speeds and bearing stability. The purchaser shall specify the minimum load.

4.5.4 Driven equipment

4.5.4.1 General

Typically the gas turbine driven equipment will comprise

a) axial compressors,

b) centrifugal compressors,

c) centrifugal pumps,

d) a.c. power generators,

or combinations thereof.