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Gas turbines — Procurement —

Part 4: Fuels and environment

Turbines à gaz — Spécifications pour l'acquisition —

Partie 4: Carburants et environnement

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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 3.

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 part of ISO 3977 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3977-4 was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

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 6: Combined cycles*

— *Part 7: Technical information*

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

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

Annex A of this part of ISO 3977 is for information only.

Introduction

This part of ISO 3977 was developed in order to establish conformity with regard to the use of gas turbine power plants. Gas turbines are being manufactured and installed at ever increasing rates. Also, there is worldwide concern over environmental related issues on both a regional and global scale. This part of ISO 3977 addresses the issues related to fuels used to operate such plants, and the emissions which are produced as a result gas turbine operation. It details the requirements which all parties should determine in advance to ensure successful installation which minimizes delays, maximizes operability, and has minimal impact on the environment.

Gas turbines — Procurement —

Part 4: Fuels and environment

1 Scope

This part of ISO 3977 provides guidelines for procurement of gas turbines with consideration of the fuel quality and of the environmental performance. Guidance is given to both the packager and purchaser on what information should be provided with regard to the fuel used by a gas turbine, and with regard to the type of information necessary to quantify the expected environmental impact. Fuel specifications are referenced but not provided.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 3977. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 3977 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 3977-3:2002, *Gas turbines — Procurement — Part 3: Design requirements*

ISO 4261:1993, *Petroleum products — Fuels (class F) — Specifications of gas turbine fuels for industrial and marine applications*

ISO 6190:1988, *Acoustics — Measurement of sound pressure levels of gas turbine installations for evaluating environmental noise — Survey method*

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

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 11086: 1996, *Gas turbines — Vocabulary*

3 Terms and definitions

For the purposes of this part of ISO 3977, the terms and definitions given in ISO 3977-1, ISO 3977-3, ISO 11086 and the following apply.

3.1
density
ρ

$$\rho = \frac{P_{\text{ref}}}{R \cdot T_{\text{ref}}}$$

where the reference temperature is typically selected as 15 °C and the reference pressure is 101,325 kPa

3.2
integrated gasification combined cycle
IGCC
process where a low quality fuel is gasified to produce a high quality fuel that meets the fuel specifications for a gas turbine

3.3
fuel-bound nitrogen
FBN
nitrogen component within the fuel which contributes to NO_x formation

NOTE This does not include nitrogen as gaseous N_2.

3.4
net specific energy
NSE
heating value determined with the combustion generated water in the vapour phase

NOTE 1 It is also known as the lower heating value. See also ISO 2314, ISO 4261 and ISO 6976.

3.5
relative density
specific gravity
⟨gaseous fuels⟩ ratio of the density of the fuel gas to the density of air

$$d = \frac{\rho_{\text{fuel}}}{\rho_{\text{air}}}$$

NOTE 1 For gases, temperature and pressures for both gases need to be specified.

NOTE 2 For liquid fuels, it is the density of the liquid fuel relative to water. The temperature of both fluids should be specified.

3.6
gross specific energy
GSE
heating value determined with the combustion generated water condensed, thus including the heat of vaporization.

NOTE It is also known as the higher heating value.

3.7
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power

NOTE 1 The reference sound power is 1 pW (= 10^{-12} W).

NOTE 2 Sound power level is expressed in decibels.

NOTE 3 Based on ISO 10494.

3.8
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure

NOTE 1 The reference sound pressure is 20 µPa (= 2×10^{-5} Pa).

NOTE 2 Sound pressure level is expressed in decibels.

NOTE 3 Based on ISO 10494.

3.9
selective catalytic reduction
SCR
post-combustion catalyst system for reduction of NO_x emissions

3.10
volatile organic compounds
VOC
hydrocarbons such as propane and butane, which can interact with NO_x to form ground level ozone

NOTE VOCs are sometimes measured and reported as unburned hydrocarbons (UHC).

3.11
Wobbe index
WI
heating value of the fuel divided by the square root of the specific gravity (relative to air)

$$WI = \frac{NSE}{\sqrt{d}}$$

NOTE Because the specific gravity of a gas is dependent upon both temperature and pressure, the conditions where the density is determined for the both the fuel and air should be specified. See annex A for examples of calculations of the Wobbe index.

3.12
normal cubic metre
m^3 (normalized)
cubic metre of gas, usually dry, referenced to 1 atmosphere (101,325 kPa) and 0 °C

NOTE Although the unit Nm^3 is used in industry, this should not be used in International Standards.

4 Symbols (and abbreviated terms)

The following terms and symbols are used in this part of ISO 3977.

ρ	density of fluid or gas
p	pressure, in kPa
T	temperature, in K or °C
CEM	continuous emissions monitoring
PEM	predictive emissions monitoring

5 Purchasers' and packagers' requirements for fuels

5.1 General

Proper use and operation of a gas turbine requires that accurate information on fuel types and fuel requirements be obtained. Both the purchaser and the packager play critical roles in this process.

If there are no International Standards available, national standards as shown in annex C of ISO 3977-3:2002 may be used as guidelines with the mutual agreement of the purchaser and packager.

5.2 Purchaser's obligations

The purchaser has the responsibility to identify all fuels to be considered for the gas turbine project of interest.

The purchaser shall provide relevant, accurate data, consistent with the proposed project. As a general outline, the purchaser shall be knowledgeable about the following:

a) site ambient conditions (i.e. temperature, pressure, relative humidity, and mean and extreme conditions of these variables and altitude);

b) expected fuel classification for the project (i.e. raw natural gas, pipeline natural gas, coke oven gas, landfill gas, IGCC medium and low energy gases, refinery gases, etc.);

c) performance/load range of the gas turbine (i.e. hours of operation, time at specific load, use of power augmentation, etc.);

d) applicable local or regional regulatory authority requirements.

The purchaser shall be able to report detailed fuel properties and contaminant levels, including limits of variability (chemical and physical characterization), to the packager for review.

5.3 Packager's obligations

The packager shall define the fuel types and ranges of fuel qualities acceptable for the gas turbine application. These may include liquid and gaseous fuels; fuel emulsions may also be considered.

Note that the packager may specify a unique reference temperature (0 °C or 15 °C, for example).

5.4 Gaseous fuels

5.4.1 General

This subclause applies to all fuels that are in the gaseous state at the gas turbine interface. In certain cases, the fuel as delivered to the site may not be in the gaseous state. If multiple fuels are available, or required over the gas turbine operating envelope, complete information shall be provided for each. Based on the fuels expected to be used on a specific project, the purchaser shall provide the range of expected properties for each of the requirements listed in 5.4.2. It shall be the responsibility of the purchaser to control the chemical and physical properties, and the contaminant levels, for the fuel gas supplied, to be within the previously agreed upon limits at all times, and to protect the gas turbine from being fueled at any time with fuel not within the agreed upon limits.

5.4.2 Chemical properties

Fuel specifications shall comply with relevant national standards. The packager shall identify general fuel properties appropriate for the purchaser’s application. The information required shall include normal chemical characteristics, and normal safety and handling properties. The purchaser shall provide the packager with the following information:

a) the full chemical composition of the proposed fuel gas(es);

b) specific energy (net and gross, both volumetric and mass basis); this may be determined analytically, or calculated from the chemical analysis;

c) Wobbe index at fuel supply temperature and pressure and the range of Wobbe index expected for fuel variations;

d) the presence of contaminants/components such as dust, rust, tar, naphthalenes, waxes or water, that may cause potential coking or fouling problems;

e) the presence of higher hydrocarbons, up to C14, if the gas turbine is to be equipped with lean-premix type combustors;

f) the minimum temperature necessary to prevent condensation at the fuel injection pressures.

Specific fuel components (or fuel additives) that may be corrosive or induce air emissions, including toxic emissions, shall be identified by the purchaser and reported to the packager for comment. The packager shall comment on the general acceptability of this fuel. The packager shall review the fuel property data, and comment on its appropriateness for the proposed gas turbine application. The packager's analysis shall be the basis for comments to the purchaser. The purchaser shall provide site emission constraints for each fuel.

5.4.3 Physical properties

For gaseous fuels, the packager shall provide technical data on pressure and temperature requirements for all fuels and fuel system components. These requirements shall include a review of the complete fuel analysis for the purchaser's application. Information furnished by the packager shall include:

a) supply pressure and temperature requirements (upper and lower limits);

b) dew point at given pressure and minimum temperature necessary to prevent condensation at fuel injection pressures;

c) minimum pressure requirements to start the gas turbine;

d) minimum pressure requirements to run the gas turbine;

e) the temperature range permissible for continuous operation;

f) filtration and liquids separation requirements;

g) allowable condensed liquids within the fuel supply to the gas turbine;

h) implications on gas fuel supply pressure from full speed no load to full load across the entire air ambient temperature range;

i) design Wobbe index range of the fuel for the gas turbine;

j) allowable gas fuel pressure variations (both short and long term).

In addition, the packager shall report on the compatibility of the fuel with specific combustion equipment, such as lean premix combustors, or other means of emissions suppression, such as water or steam injection.

5.4.4 Fuel treatment

To comply with packager and ISO 4261 fuel requirements, fuel treatment may be required. Based upon the physical and chemical properties of the fuel, the purchaser is responsible for providing fuel gas conditioned to the required specifications.

5.4.5 Emissions

Fuel properties will impact combustion generated pollutants. The packager is responsible for identifying the exhaust emissions for particular fuel types. The purchaser shall provide detailed fuel analyses (or fuel samples) to make an accurate emission projection. Properties of interest include:

a) chemical analysis (carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine);

b) gas compositional analysis (reporting to concentrations that are below detection limits using gas chromatography);

c) specific energy (net and gross);

d) the presence of reactive gases such as alkynes (e.g. acetylene).

All tests of fuel properties shall correspond to standardized procedures such as those specified in International Standards.

The purchaser shall provide site emissions constraints for each proposed fuel.

5.4.6 Startup and shutdown

In some cases, the base fuel may not be available or acceptable for gas turbine ignition, startup and shutdown. The packager shall specify the amount and quality of the startup and shutdown fuel (liquid or gas) required, as well as its minimum pressure and temperature requirements.

5.4.7 Safety and handling aspects

5.4.7.1 Non-traditional fuels

Fuel gases can come from non-traditional sources. Unusual fuel compositions can present specific safety and handling problems. Some hazards are associated with combustion properties of the fuel (such as hydrogen or acetylene) while other hazards are associated with the toxicity. The purchaser shall alert the packager to the presence of unusual components in the fuel. The packager shall review all the fuel components of concern and comment, where appropriate, on safety and handling aspects. For equipment beyond the packager's scope of supply, the purchaser is responsible to inform vendors of potential safety issues. A brief list of non-traditional fuel sources includes:

a) refinery gases that may be high in hydrogen;

b) coke oven gases that may be high in carbon monoxide;

c) raw natural gases that may have high hydrogen sulfide levels;

d) syngas (or synthetic gas) derived from a low quality fuel gasification process, such as an IGCC;

e) landfill and digester gas;

f) fuel gases that are heavier than air, and hence may collect or pool in recessed areas.

Examples of key fuel hazards are described in 5.4.7.2 and 5.4.7.3.

5.4.7.2 Hydrogen content

Due to its wide flammability limits and low density, the presence and concentration of hydrogen in the fuel shall be carefully evaluated. Appropriate ventilation, gas detection and explosion proofing shall be provided by the packager. (This is applicable to the gas turbine enclosure and fuel gas compartment enclosures only.)

5.4.7.3 Explosion proofing/leak detection

In addition to the emphasis on hydrogen, all gaseous fuels shall be properly considered in the design of the fuel system and its surroundings. Fuels heavier than air shall not be allowed to collect in low points where ignition might occur. Applicable codes and standards for hazardous classification and equipment design shall be mutually agreed upon between the purchaser and packager. The purchaser shall inform the packager of any local regulation on the subject. The packager shall define the locations of vents or purge lines to which the purchaser's connections are required.

5.5 Liquid fuels

5.5.1 General

This subclause applies to all fuels which are in a liquid state at the gas turbine enclosure limits. If multiple fuels are available or required over the gas turbine operating envelope, the purchaser/operator shall provide the range of expected properties for each grade of fuel considered. It shall be the responsibility of the purchaser/operator to control chemical and physical properties, and the contaminant levels for the specified fuels, to within previously agreed limiting values at all times, and to protect the gas turbine from receiving fuel not within the agreed limits.

The purchaser (or subsequent owner of the equipment) shall inform the packager of any changes in the fuel properties or fuel quality which allow the fuel to fall outside of the initial requirements.

The packager shall provide general fuel requirements for the operation of the gas turbine, including acceptable grades according to ISO 4261. The packager shall also provide information on the compatibility of specific combustion equipment designs, such as pre-mixed combustors with specific grades (or properties) of fuels.

5.5.2 Chemical properties

Fuel specifications shall comply with ISO 4261 or equivalent national standards. The packager shall identify general fuel properties appropriate for the purchaser’s application. These include physical properties, combustion properties, aromatic contents, safety and handling properties and trace components.

A comprehensive fuel analysis shall be submitted to the packager describing all critical fuel properties (see also ISO 4261). Where the proposed liquid fuels being considered are not of Class A1 or A2 distillate quality, the purchaser shall provide the packager with a sample of approximately 4 litres for evaluation.

Combustion-generated emissions depend upon liquid fuel properties and quality.

The purchaser shall assume responsibility for providing information on specific fuel properties relevant to combustion-generated emissions. These include:

a) fuel-bound nitrogen (FBN);

b) fuel sulfur;

c) asphaltene content (heavy oils);

d) aromatic content;

e) carbon residue (heavy oils);

f) carbon/hydrogen ratio;

g) net specific energy (NSE) and gross specific energy (GSE).

The fuel properties outlined in the agreement between the packager and purchaser determines some of the equipment selection and operating conditions of the gas turbine system. If at a later date the purchaser desires to

use a fuel outside the original agreed-upon limits, the purchaser shall inform the packager accordingly, and shall supply a complete analysis or sample for evaluation and requalification in the same manner as outlined above.

5.5.3 Physical properties

The packager shall identify general fuel handling and processing requirements for the gas turbine. These shall include, as a minimum, the following:

a) fuel viscosity (at two temperatures);

b) vapour pressure;

c) sediments;

d) ash;

e) water;

f) additives (either present or required) and the concentration or addition rate;

g) flash point;

h) boiling point;

i) end point;

j) cold filter plugging point (ISO 4261);

k) density.

The packager shall identify general fuel handling and processing requirements for the gas turbine. These shall include, as a minimum, the following:

a) general property requirements for acceptable fuel grades;

b) viscosity requirements (both start-up and normal operations);

c) fuel heating or insulation requirements;

d) removal or control of corrosive agents;

e) allowable additives for control of combustion and corrosion problems.

In addition, the packager shall report on the compatibility of the fuel with specific combustion equipment, such as lean premix combustors, or post-combustion equipment such as a duct burner or SCR.

5.5.4 Fuel treatment

5.5.4.1 General

Fuel treatment consists of those operations which modify the condition of the fuel in the storage tank to meet specific requirements at the gas turbine. The objective is to bring the fuel to conditions required by the packager. This can include fuel washing, settling, or inclusion of additives to neutralize undesirable agents which cannot be removed from the fuel.

The packager shall define the maximum permissible levels of all relevant components from all sources (i.e. fuel, air, wash liquids, water, steam, etc.). Some liquid fuels may contain agents corrosive to the gas turbine hot gas path components: sodium (Na), potassium (K), vanadium (V), lead (Pb), etc. The purchaser is responsible for qualitative

and quantitative fuel monitoring to assure compliance with the packager specification. Also, the packager may make recommendations on the methods used to quantify the presence of these components.

Ash-forming liquid fuels may require fuel treatment (e.g. extraction of alkaline metals or the inhibition of the fuel bound vanadium). Ash-forming fuels are often characterized by their density or source of feedstock. These fuels include: heavy oil, residual oil, crude oil. Specifying the requirements for fuel treatment and fuel supply based on fuel quality is the responsibility of the packager; ensuring that the agreed limits are not exceeded remains the responsibility of the purchaser.

5.5.4.2 Washing

For fuels that may require washing, the packager shall comment on the washing requirements after considering the fuel quality and the application. Fuel oil washing is accomplished by continuous addition of demineralized water and a demulsifying detergent to the fuel oil. The water is then separated from the oil by centrifugal or electrostatic forces. Although water and oil are immiscible liquids, the density difference between heavy oil and salty water must not lie below the limitation given by the treatment plant supplier to ensure the complete separation of water from the fuel oil.

5.5.4.3 Inhibition

If heavy fuels containing vanadium are specified by the purchaser, the packager shall give requirements for additives for vanadium inhibition. The packager's fuel specification shall include allowable and recommended fuel grades. Also, the packager shall give the maximum permissible turbine entry temperature based on the presence of fuel contaminants or fuel additives.

5.5.5 Emissions

Fuel properties will impact combustion generated pollutants. The packager is responsible for identifying the exhaust emissions for particular fuel types. The purchaser shall provide detailed fuel analyses (or fuel samples) to make an accurate emission projection. Properties of interest include those referenced in 5.5.2 and 5.5.3.

All tests of fuel properties shall correspond to standardized procedures.

The purchaser shall provide site emissions constraints for each proposed fuel.

5.5.6 Start-up and shutdown

The packager shall specify if an auxiliary start-up/shutdown fuel is needed and define the requisite fuel qualities or properties and the amount required.

5.5.7 Safety and handling

5.5.7.1 General

Safety and handling requirements shall be reviewed by the packager based on information supplied by the purchaser.

5.5.7.2 Storage

Adequate fuel storage and handling practices shall be employed to minimize water and other contaminants in the fuel. These include settling the fuel oil prior to use, floating suction provisions, and periodic removal of water from the bottom of the tank. In applications where adequate settling periods cannot be accommodated, rapid purification equipment such as centrifuges or electrostatic separators may be required. The overall fuel system design shall avoid sludges or water, and any clean-up system shall have the capability to remove sludges. Fuel storage vessels shall be enclosed within a beamed area that meets local or regional regulatory authority requirements.

5.5.7.3 Vapour pressure

For volatile fuels (such as light oils or naphthas), the purchaser shall provide the vapour pressure of the fuel at a specific reference temperature.

5.5.7.4 Explosion proofing/leak detection

Leak detection and explosion hazards relevant to volatile hydrocarbon fuels shall be considered in the design. Applicable codes and standards for hazardous classification and equipment design shall be mutually agreed upon between the purchaser and packager. The purchaser shall inform the packager of any local regulation on the subject. The packager shall define the locations of vents or purge lines to which the purchaser's connections are required.

5.5.7.5 Viscosity/lubricity

The packager shall identify acceptable ranges of fuel viscosity for each application. Fuel analyses (including fuel lubricity, particularly for light fuel oils) or samples shall be provided for determination of flow properties. In the case of heavy fuel oils, the packager shall provide information on fuel heating requirements. These include:

a) maximum fuel temperature permitted;

b) minimum fuel temperature required.

For low lubricity liquid fuels, the purchaser shall inform the packager of the intent to use or operate on fuels of such quality.

6 Environmental requirements

6.1 General

Environmental issues include primarily emissions during start-up, shutdown and general operation. Emissions of interest are noise (acoustic), combustion-generated emissions, and possibly thermal emissions. These topics are described in the following subclauses.

6.2 Noise emissions

6.2.1 Responsibilities

The packager shall be responsible for providing estimates of sound emission levels from equipment within the packager’s scope of supply. The purchaser shall inform the packager of the presence of other sound producing or absorbing structures, the absorbing effect of the ground and the barrier effect of other buildings. The purchaser shall also provide specific site details that include a general site description, topography, meteorological data, and physical arrangements. In the absence of such information, idealized site characteristics of flat, unobstructed terrain, with non-absorbing ground surface, and an absence of reflective or barrier surfaces shall be assumed. The purchaser shall identify the location of noise-sensitive areas, and any applicable statutory noise requirements.

6.2.2 Expression of results

Sound measurements shall be reported as follows:

a) sound pressure level (ref. 2×10^{-5} N/m^2), sound intensity level ref. 10^{-12} W/m^2) emitted by each source at a specified position;

b) sound power level (ref. 10^{-12} W), calculated according to sound pressure or sound intensity level.

The relevant instrumentation frequency weighting, typically “A” or “C”, shall be specified.

6.2.3 Reference methods for sound/noise measurements

The measurement of sound pressure level shall be carried out according to

a) ISO 6190 in the far field, either within the plant boundaries if the measurement position is far enough from the noise sources of the plant or outside the plant boundaries, or

b) ISO 10494 in the near field (1 m from the major surfaces of the source). The guaranteed result shall be the average sound levels measured from the perimeter of the unit(s) and the auxiliary equipment.

The calculation of sound power levels shall be performed according to ISO 10494.

6.2.4 Reporting values

The packager shall provide technical data on noise/acoustical emissions from the equipment supplied. Reporting standards shall be based on the requirements of ISO 10494.

6.2.5 Sound level within gas turbine enclosure

The packager shall report estimated sound levels inside the enclosure for the purpose of occupant safety only. If the enclosure is not accessible, this requirement shall be waived.

6.2.6 Sound level outside of the gas turbine enclosure (near and far field)

Sound emissions shall be considered beyond the turbine enclosure.

a) In the near field (1 m from the source and 1,5 m above the ground): the relevant standard is ISO 10494.

b) In the far field: it is preferable that the distance form the source envelope (smallest rectangle enclosing all relevant equipment) be at least 50 m, or 1,5 times the largest dimension of the source envelope, but not more than 200 m. The relevant standard is ISO 6190.

6.2.7 Sounds produced from different sources near the gas turbine

The turbine packager shall make responsible efforts to quantify the sound level emission from the turbine, taking into consideration the background noise levels provided by the purchaser. The packager shall define specific sound sources from the turbine, exclusive of sources installed by packagers beyond the scope of the turbine packager's control. Sound power levels and spectral distribution in octave bands shall be reported.

6.3 Exhaust emissions

6.3.1 General

Emissions from gas turbines come in the form of solids, liquids, gases and vapours. For natural gas operation, gases and vapours are the components of primary concern. Particulate/smoke emissions are very low and difficult to measure when using gaseous fuels. In the case of liquid fuels, particulates (solid and condensibles) can be adequately measured and quantified.

6.3.2 Responsibilities

Exhaust emissions for the specified fuels shall be known and provided by the packager. Technical information on the emission response shall be based on customer needs and regulatory requirements. Emissions will normally be coupled to specific fuel properties, site conditions, and the operating profile of the turbine. The purchaser shall inform the packager in a commonly spoken/written language about relevant environmental regulations and restrictions existing or being developed.

6.3.3 Reporting values

Emissions values provided by the packager shall be reported in a consistent manner. All emission values shall be reported using a standardized measurement system. When emissions are reported normalized to the fuel specific energy, the use of net or gross specific energy shall be explicitly stated. Examples of emission reporting methods are as follows:

a) gas/vapour emission concentrations reported on a dry basis (the common reporting basis is corrected to 15 % oxygen);

b) gas/vapour emission concentrations reported on a dry basis, but with a correction to a specific reference oxygen level;

c) emissions reported on a mass flow basis;

d) emissions reported on a mass per unit energy basis;

e) VOC (UHC) emissions reported on an “as methane” or “as propane” basis;

f) emissions reported on a density concentration basis [e.g. mg/m^3 (normalized) corrected to a specific oxygen content];

g) filter stain and plume opacity methods reported to quantify smoke or particulate emissions.

When reporting emissions on a density basis, the reference temperature and pressure shall be clearly defined.

For solid particulate emissions, the following formats are appropriate:

a) emissions reported on a density basis [mg/m^3 (normalized), mass of particulate per volume of exhaust gas];

b) emissions reported on a mass flow basis;

c) emissions reported on mass per unit energy basis.

6.3.4 Gaseous emissions

The packager shall be able to provide information at required engine loads for the following emissions:

a) NO_x (gas), both NO and NO_2 may be required in some cases;

b) CO (gas);

c) unburned hydrocarbons (gas);

d) volatile organic compounds (VOC) (gas);

e) opacity or visibility;

f) SO_2.

The definition of VOC shall be according to ISO 11042-1 (unburned hydrocarbons, excluding CH_4 and C_2H_6). Clarification on the definition of VOCs may be required. Additionally, the composition of the permanent gases (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. For gaseous emissions, information from the packager shall be available in any of the following formats as requested by the purchaser:

a) concentration basis (wet or dry basis, depending upon purchaser’s requirements);

b) mass rate basis, usually on an hourly rate basis;

c) normalized to engine heat input.

The methods used for the measurement and evaluation shall be in accordance with ISO 11042-1 or ISO 11042-2, or applicable local or regional regulatory authority requirements or standards.

6.3.5 Particulates

6.3.5.1 General

Particulate emissions are produced with most fuels, but are of concern only with liquid fuels. Particulate emissions with gaseous fuels are not zero, but are often below detection limits of most measurement equipment. In the case of gas fuels, providing particulate emissions is not recommended.

6.3.5.2 Particulate and smoke emissions with liquid fuels

Particulate emissions include solid and liquid components. These contribute to a visible smoke plume and formation of haze. The packager shall be able to provide reasonable estimates of particulate emissions based on knowledge of fuels compatible with the turbine fuel specification. Emissions shall be sufficiently understood to identify

a) solid particulates produced in combustion,

b) sulfates formed in the post-combustion process for emission abatement, and

c) particulates released by the ash in the fuel.

6.3.5.3 Smoke/opacity

6.3.5.3.1 General

Smoke is a visual indicator of particulate emissions. However, particulates are not the only exhaust species which can impact plume visibility. The purchaser shall be aware that the presence of NO_2 in the exhaust can also contribute to a visible plume.

6.3.5.3.2 Smoke

Smoke is an emission property that is highly correlated to turbine particulate emissions and fuel quality. High particulate loadings can produce a visible smoke plume. Smoke emitted from gas turbines is normally evaluated in two ways: visible plume opacity and the filter stain method. The purchaser shall be aware that there are no effective techniques defining the relationship between visible smoke emissions and total particulates loading. The purchaser shall also be aware that the smoke/particulate emissions provided by the packager are valid only at specific exhaust temperature, pressure and humidity conditions; and assume zero loading from local ambient air.

The purchaser shall be aware that the presence of control technologies at the exhaust can affect these same emissions. Supplementary equipment, such as a duct burner, heat recovery steam generator (HRSG), oxidation catalyst, can all affect the exhaust smoke/opacity. The purchaser has the responsibility to obtain information from vendors on the impact of any equipment in the exhaust flow path.

Opacity/smoke emissions may be reported in the following manner:

a) optical opacity/density, as measured by a transmissometer;

b) by the filter stain method;

c) by visual inspection.

6.3.5.3.3 Opacity

The packager shall quote opacity levels based on optical absorption (percent absorption). When required, Bacharach Numbers (see ISO 5063) may be used. This information shall consider stack dimensions (height, diameter) and atmospheric conditions. Visual opacity shall be based on emissions from a single exhaust stack. The purchaser assumes the responsibility for incorporating these emissions into total plant.

6.3.5.4 Water or steam injection

If water or steam injection is used for NO_x control, the packager shall define the water quality and quantity requirements. The impact on power output and thermal efficiency shall be provided.

6.3.5.5 Evaporative cooler applications

In evaporative cooler applications, the packager shall define the water quality and quantity requirements, and specify the compatibility of various evaporative systems, their location and limitations, if any.

6.3.5.6 Post-combustion controls

The impact of post-combustion controls on all emissions is important. However, this is not the principal responsibility of the packager. For example, oxidation catalysts will 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 emission levels. It is the responsibility of the purchaser to evaluate the impact of all post-combustion control technologies on the exhaust emission signature.

6.3.5.7 Emission monitoring

The purchaser and packager shall define responsibility for providing continuous emissions monitoring (CEM) and/or predictive emissions monitoring (PEM) if required to meet local or regional regulatory authority requirements. Species normally capable of direct monitoring include NO_x, CO, O_2, UHC, SO_2 and opacity. Particulates cannot normally be monitored on a continuous basis.

The purchaser is also responsible for selecting equipment, and the installation and warranty of emission monitoring equipment. All maintenance requirements of CEM shall be the purchaser's responsibility. The purchaser is responsible for defining the reporting, data collection, storage, data processing and quality assurance/quality control (QAQC). These are normally established by the local or regional regulatory authorities.

6.3.5.8 Verification of emissions

The gas turbine is often part of a more complex facility that may include an HRSG, duct burner, SCR, etc. The purchaser shall be aware of the extreme difficulty of verifying the emission performance of each component. The purchaser shall inform the packager of the integrated plant design. Where required, the purchaser, packager and other vendors shall develop a plan to evaluate emission performance of plant components.

6.3.5.9 Background conditions

In some cases, it is possible to encounter emission requirements more stringent than the pre-existing ambient air quality. The purchaser shall be aware that the packager’s equipment is not designed to function as an air cleaning system. The packager assumes all exhaust emissions are net emissions, above those pre-existing in the ambient air.

6.3.6 Other emissions

6.3.6.1 General

Other relevant emissions which shall be considered include thermal emissions and water discharge.

6.3.6.2 Plant thermal emissions

Plant thermal emissions are released into the air, and can be released into the water during operation. The packager shall, if available and if requested, provide technical information to allow the purchaser to estimate relevant plant thermal emissions. These can include stack thermal loss or discharges of water from the gas turbine. Local regulations may dictate the allowable thermal emission limits from a turbine or plant. The purchaser shall be aware of relevant local, regional, national or international regulations in this area.

6.3.6.3 Water discharges

Water releases by a gas turbine include rainwater runoff, cooling water, compressor wash-water, turbine wash-water, evaporative cooler blowdown, and water or steam for NO_x control or power augmentation. The packager shall provide information on the expected quantities, rates and presence of contaminants from discharges associated with gas turbine functions.

6.3.6.4 Construction issues

The purchaser is responsible for issues relevant to the construction, fabrication and installation of the gas turbine and its support equipment. Relevant issues at this phase include, but are not limited to, noise generated during construction, rainwater run-off, possible water contamination, waste generation, and emissions from construction equipment or fires

6.3.6.5 Fuel gas (venting)

Under some circumstances, fuel gases can be released into the environment during the course of plant operation. The purchaser is responsible for ensuring that these emissions are controlled, and is responsible for logging and report such releases to appropriate agencies.

6.3.6.6 Lube oil demister

Lube systems can release oil vapours into the environment through the demister. The purchaser is responsible for properly specifying and maintaining this equipment to minimize the loss of lube oil through this system. Some environmental agencies may also require that such releases be reported. It is the responsibility of the purchaser to provide this information on a timely basis.

Annex A
(informative)

Calculation of Wobbe index

Packagers may use different approaches for calculating the Wobbe index. This is particularly critical for low heating value gases, or in applications where the fuel gas is heated or cooled prior to combustion.

$$WI = \frac{NSE}{\sqrt{\rho_{gas}(p, T) / \rho_{air}(p_{ref}, T_{ref})}}$$

where

ρ_{gas} is the density of the gas;

ρ_{air} is the density of the air;

p is the fuel pressure (kPa);

T is the fuel temperature (°C);

p_{ref} is the air reference pressure (101,325 kPa);

T_{ref} is the air reference temperature (0 °C);

NSE is the net specific energy of the fuel [kJ/m^3 (normalized)].

In this example, the fuel temperature and pressure are at a specific location unique to the packager's design requirements.

Another Wobbe index method used by some packagers includes a separate qualifier for the fuel gas temperature:

$$WI = \frac{NSE}{\sqrt{d \cdot T_{gas}}}$$

where

d is the gas specific gravity, with quantities referenced to 15 °C and 101,325 kPa;

T_{gas} is the absolute temperature of the fuel gas;

NSE is the net specific energy of the fuel [kJ/m^3 (normalized)].

Because the reference temperatures are sometimes established at different values, the temperatures where the gas density and gas heating value are evaluated should be stated explicitly.

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