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Gas turbines — Acceptance tests

Turbines à gaz — Essais de réception

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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 2314 was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

This third edition cancels and replaces the second edition (ISO 2314:1989), which has been technically revised. It also incorporates the Amendment ISO 2314:1989/Amd.1:1997 and the Technical Corrigendum ISO 2314:1989/Cor.1:1997.

Introduction

This International Standard specifies guidelines and procedures for preparing, conducting and reporting thermal-acceptance tests in order to determine and/or verify electrical power output, mechanical power, thermal efficiency (heat rate), turbine exhaust gas energy and/or other performance characteristics of gas-turbine power plants and gas turbine engines, in this International Standard referred to as “gas turbines”. It is necessary that such performance test results be determined with a high level of accuracy using best engineering knowledge and industry practice in measurement technique and method.

It is necessary that a detailed, project-specific or test-equipment-specific test procedure be prepared by the party executing the performance test, based on the recommendations and guidelines given in this International Standard as well as considering contractual obligations. It is necessary that any deviations from this International Standard be mutually agreed upon by the involved parties prior to the start of the test.

Gas turbines — Acceptance tests

1 Scope

This International Standard applies to open-cycle gas-turbine power plants using combustion systems supplied with gaseous and/or liquid fuels as well as closed-cycle and semi-closed-cycle gas-turbine power plants. It can also be applied to gas turbines in combined cycle power plants or in connection with other heat-recovery systems.

In cases of gas turbines using free-piston gas generators or special heat sources (for example synthetic gas of chemical processes, blast furnace gas), this International Standard can be used as a basis but suitable modifications are necessary.

Acceptance tests of gas turbines with emission control and/or power augmentation devices that are based on fluid injection and/or inlet air treatment are also covered by this International Standard and it is necessary that they be considered in the test procedure, provided that such systems are included in the contractual scope of the supply subject to testing.

Comparative testing can be subject to many different scenarios, depending on the purpose of the conducted measures. This International Standard can also be applied to comparative tests designed to verify performance differentials of the gas turbine, primarily for testing before and after modifications, upgrades or overhaul, although no special reference is made to these topics.

This International Standard also includes procedures for the determination of the following performance parameters, corrected to the reference operating parameters:

a) electrical or mechanical power output (gas power, if only gas is supplied);

b) thermal efficiency or heat rate;

c) turbine exhaust energy (optionally exhaust temperature and flow).

It is necessary that any other performance parameters defined in the contract between equipment supplier and purchaser be considered accordingly in the specific test procedure as well as in the supplier's standard manufacturing test procedure.

This International Standard describes measurement methods and corresponding instruments employed and their calibration arrangement and handling. It includes provisions for preparing and conducting a performance test, defines operating conditions of the gas turbine, boundary conditions and their limits as well as standard conditions (3.9) that should be used as a reference if no other conditions are agreed at the time of purchase. Furthermore, it contains provisions for the measurement data recording and handling, methods for the calculation and correction of the test results as well as the development of the uncertainty thereof.

Test tolerance is not addressed in this International Standard, because it is considered a commercial term not based on statistical analysis of measurement results. It is necessary that the methodology on how to apply tolerances for the demonstration of compliance with the guaranteed values be defined in the contract.

For the optional test to determine exhaust energy and/or flow, these values are determined from an energy balance around the gas turbine. Uncertainty values can be minimized by achieving the limits defined in this International Standard for the key parameters in the energy balance.

This International Standard does not apply to the following:

a) emission testing;

b) noise testing;

c) vibration testing;

d) performance of specific components of the gas turbine;

e) performance of power augmentation devices and auxiliary systems, such as air inlet cooling devices, fuel gas compressors, etc.;

f) conduct test work aiming at development and research;

g) adequacy of essential protective devices;

h) performance of the governing system and protective systems;

i) operating characteristics (starting characteristics, reliability testing, etc.).

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.

ISO 2533, *Standard atmosphere*

ISO 3733, *Petroleum products and bituminous materials — Determination of water — Distillation method*

ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

ISO 6245, *Petroleum products — Determination of ash*

ISO 6974-1, *Natural gas — Determination of composition with defined uncertainty by gas chromatography — Part 1: Guidelines for tailored analysis*

ISO 6975, *Natural gas — Extended analysis — Gas-chromatographic method*

ISO 6976 *Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition*

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

ISO 10715, *Natural gas — Sampling guidelines*

ISO 12213-2, *Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis*

ISO 14596, *Petroleum products — Determination of sulfur content — Wavelength-dispersive X-ray fluorescence spectrometry*

ISO 20846, *Petroleum products — Determination of sulfur content of automotive fuels — Ultraviolet fluorescence method*

ASTM D4629 *Standard Test Method for Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection*

ASTM D5291, *Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants*

DIN 51451, *Testing of petroleum products and related products — Analysis by infrared spectrometry — General working principles*

3 Terms and definitions

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

3.1
degradation
loss of performance of a gas turbine due to wear and tear experienced in normal operation which is not recoverable by compressor cleaning, turbine cleaning, filter cleaning, etc.

NOTE 1 This can also be referred to as ageing.

NOTE 2 Adapted from ISO 3977-9:1999, 4.1.7.

3.2
equivalent operating hours
weighted operating events affecting the life of the gas turbine forming an equivalent operating time to determine inspection intervals of life expectancy

NOTE Adapted from ISO 3977-9:1999, 4.1.2.2.

3.3
gas generator
assembly of gas turbine components that produces heated, pressurized gas and provides it to a process or to a power turbine

NOTE Adapted from ISO 3977-1:1997, 2.14.

3.4
gas turbine
machine that converts thermal energy into mechanical work

NOTE 1 It consists of one or several rotating compressors, thermal device(s) that heat the working fluid, one or several turbines, a control system and essential auxiliary equipment. Any heat exchangers (excluding waste exhaust heat recovery exchangers) in the main working fluid circuit are considered as part of the gas turbine.

NOTE 2 Adapted from ISO 3977-1:1997, 2.1.

3.5
heating value
calorific value
specific energy
amount of heat released by the complete combustion in air of a specific quantity of gas or liquid fuel when the reaction takes place at constant pressure

NOTE If the combustion products accounted for are only in the gaseous state, the value is called lower heating value, LHV, or inferior calorific value or net heating value. If the combustion products are gaseous with the exception of water, which is in liquid state, the value is called higher heating value, HHV, or superior calorific value or gross heating value at 15 °C for natural gas fuel.

See ISO 6976.

3.6
power
quantity that may be expressed in terms of mechanical shaft power at the turbine coupling, electrical power of the turbine-generator or gas power in the case of a gas turbine or gas generator producing gas or compressed air

3.7
random error
result of a measurement minus the mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions

See ISO/IEC Guide 99:2007, 2.19.

3.8
reference standard
standard, generally having the highest metrological quality available at a given location or in a given organization, from which measurements are derived

See ISO/IEC Guide 99:2007, 5.6.

3.9
standard reference conditions
conditions as defined in ISO 2533, equal to the following:

a) for the ambient air or intake air at the compressor flange (alternatively, the compressor intake flare):

— absolute pressure of 101,325 kPa (1,013 25 bar; 760 mm Hg),

— temperature of 15 °C,

— relative humidity of 60 %;

b) for the exhaust at turbine exhaust recuperator outlet, if a recuperator cycle is used:

— static pressure of 101,325 kPa

NOTE 1 In the case of the closed cycle, the standard conditions for the air heater are 15 °C and 101,325 kPa for the ambient atmospheric air.

NOTE 2 An inlet water temperature of 15 °C applies if cooling of the working fluid is used.

3.10
systematic error
bias
mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions minus a true value of the measurand

See ISO/IEC Guide 99:2007, 2.17.

3.11
thermal efficiency
ratio of the power output to the heat consumption based on the lower heating value, LHV, or net heating value of the fuel

NOTE Adapted from ISO 3977-1:1997, 2.3.4.

3.12
heat rate
ratio of the fuel energy supplied per unit time to the power produced

NOTE 1 The heat rate is expressed in units of kilojoules per kilowatt hour.

NOTE 2 It is widely used in the power generation industry.

See ISO 11086.

3.13
tolerance
allowed deviation from a specific requirement

3.14
traceability
property of the result of a measurement or the value of the standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

NOTE Adapted from ISO/IEC Guide 99:2007, 2.41.

3.15
turbine inlet temperature
TIT
defined arbitrarily as a theoretical flow-weighted mean temperature before the first-stage stationary blades calculated from an overall heat balance of the combustion chamber with the gas mass flow from combustion mixed with the turbine cooling air mass flows prior to entering the first stage stationary blades

3.16
turbine outlet temperature
TOT
temperature of the hot gas leaving the turbine

3.17
type A evaluation
〈of uncertainty〉 method of evaluation of uncertainty by the statistical analysis of series of observations

See ISO/IEC Guide 98-3.

3.18
type B evaluation
〈of uncertainty〉 method of evaluation of uncertainty by means other than the statistical analysis of series of observations

See ISO/IEC Guide 98-3.

3.19
uncertainty
〈of measurement〉 shortened form of “uncertainty of measurement”, a parameter associated with the result of a measurement, that characterizes the dispersion of the values that can reasonably be attributed to the measurand

NOTE 1 The determination of the quality of a measurement that can be expressed with the uncertainty of the test result is of fundamental importance in any field of measuring and testing. A measure to quantify such quality is the uncertainty of measurement. The shortened term “uncertainty” is used for simplicity in this International Standard.

NOTE 2 The expression “accuracy of measurement” (closeness of the agreement between the result of a measurement and the value of the measurand), commonly abbreviated as “accuracy,” is not associated with numbers and is not used as a quantitative term.

See ISO/IEC Guide 99:2007, 2.26.

3.20
working standard
standard that is used routinely to calibrate or check material measures, measuring instruments or reference materials

See ISO/IEC Guide 99:2007, 5.7.

4 Test boundary

The test boundary concept encompasses the hardware scope of the gas turbine subject to performance testing considering the reference conditions for the given guaranties. It provides the basis for the definition and layout of instrument number, range and location required to determine the energy streams crossing the test boundary as well as to determine the actual conditions during testing for correcting the test results to reference conditions.

Figure 1 shows a typical test boundary for the scope of an open cycle gas turbine for electrical output application with the measurement stations needed for the performance determination. The measurement stations within the test boundary may be used for energy balance calculation as demonstrated in Chapter 8.

The given nomenclature is used for the example calculations in this International Standard.

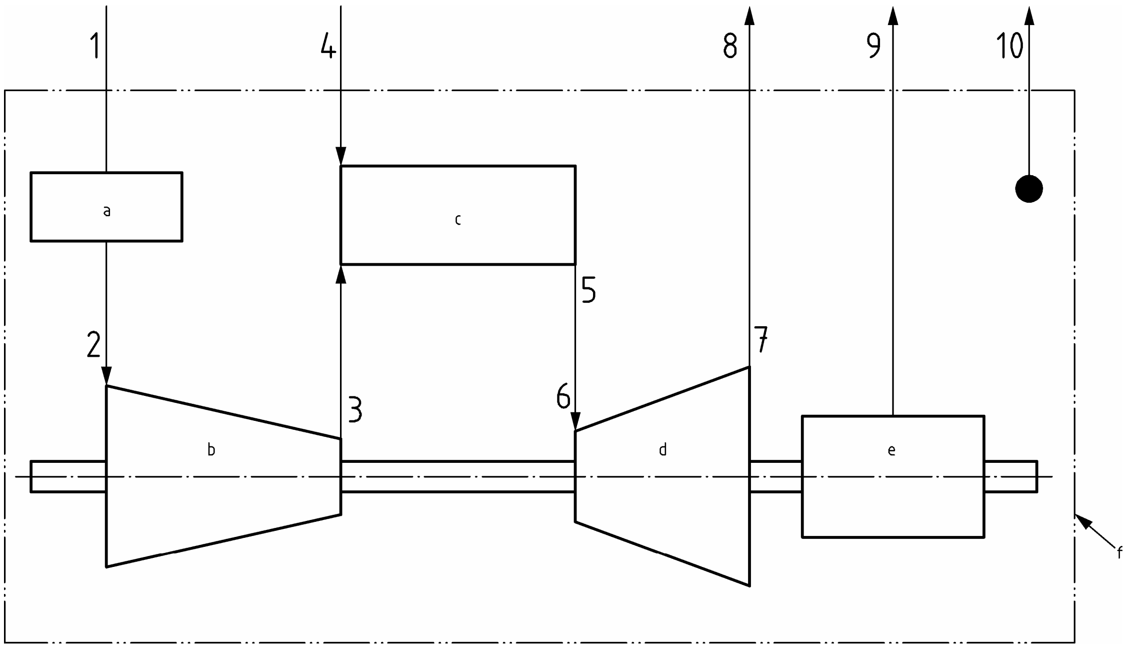

Figure 1 – Test Boundary for Generator Application

a	Air filter	d	Turbine(s)
b	Compressor(s)	e	Generator
c	Combustor(s)	f	Test boundary for generator application

The typical test boundary for mechanical drives is shown in Figure 2.

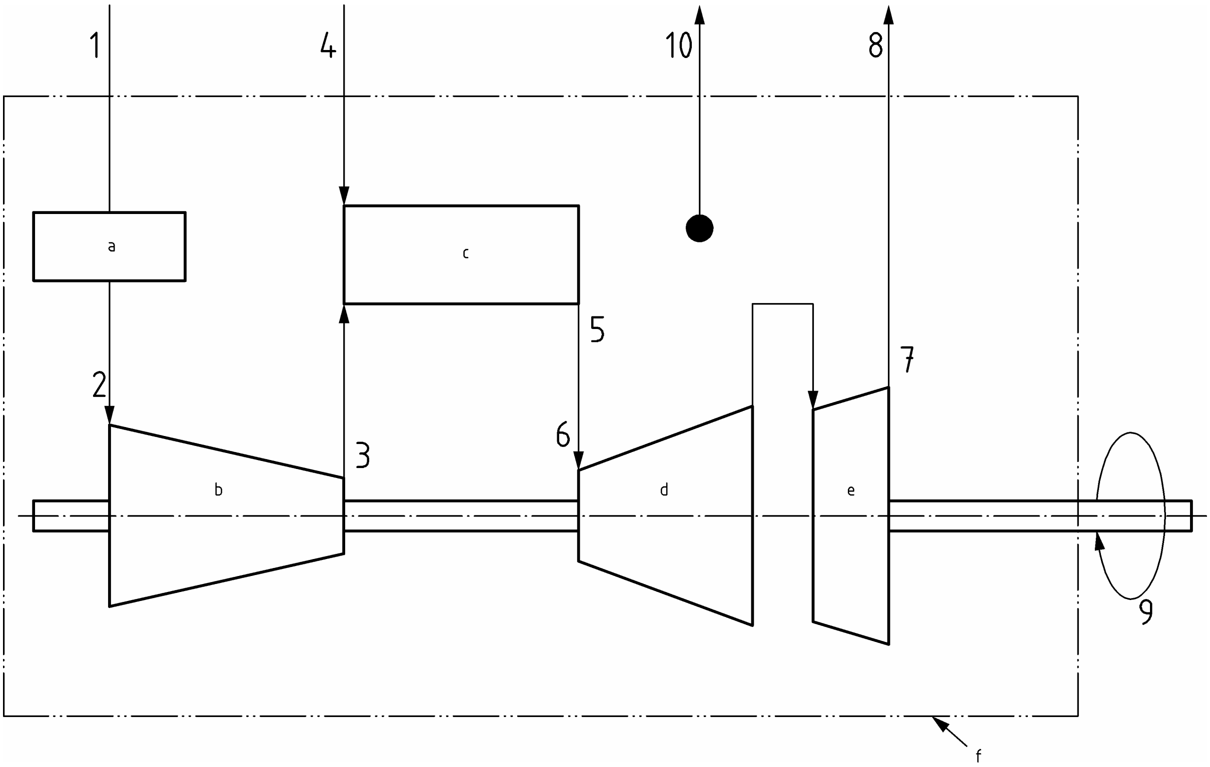

Figure 2 – Test Boundary for Mechanical Drive Application

a	Air filter	d	Turbine(s)
b	Compressor(s)	e	Power Turbine
c	Combustor(s)	f	Test boundary for mechanical drive application

Station names are given in Table 1

Table 1 – Station identification nomenclature

Station		Measurands
1	Ambient air	Temperature, pressure, humidity
2	Compressor inlet	Temperature, pressure
3	Compressor outlet	Temperature, pressure
4	Fuel + injection fluid	Flow, temperature, pressure, fuel properties
5	Combustor outlet	N/A
6	Turbine inlet	N/A
7	Turbine exhaust	Temperature, pressure
8	Stack exhaust	Temperature
9	Electrical power	Active power, power factor, frequency, voltage, current
	Shaft power	Torque, rotor speed
10	Losses	Thermal, mechanical, electrical

Note Any additional streams crossing the test boundary should be accounted for.

The losses are needed for the determination of the gas turbine exhaust energy and include all energy fluxes leaving the test boundary. Such losses are typically radiation losses, bearing and gear losses, generator losses and thermal losses. An example for the latter is heat dissipation from compressor air cooling systems in combination with a heat recovery boiler of a combined cycle plant.

Generally the losses have a small influence on the calculated gas turbine exhaust energy and therefore are often taken as constant design value rather than measured. An exception is the heat extracted from cooling systems, which may be determined based on measured flow, temperature and pressure.

5 Symbols

The symbols and nomenclature used in this International Standard are given in Table 2, together with the physical unit.

Table 2 – Symbols

Symbol	Definition	Unit
$C_{P,i}$	Correction factor for power output	-
$C_{P,i,a}$	Correction factor for power output, from measured to standard reference conditions	-
$C_{P,i,b}$	Correction factor for power output, from specified to standard reference conditions	-
$C\eta,i$	Correction factor for thermal efficiency	-
$C\eta,i,a$	Correction factor for thermal efficiency, from measured to standard reference conditions	-
$C\eta,i,b$	Correction factor for thermal efficiency, from specified to standard reference conditions	-
$\cos\varphi$	Generator power factor	-
$c_{p,a1}$	Specific heat (heat capacity) at constant pressure of air	kJ / (kg ·K)

Table 2 (*continued*)

Symbol	Definition	Unit
$c_{p,i}$	Specific heat (heat capacity) of gases at constant pressure	kJ / (kg · K)
$c_{P,g7}$	Specific heat (heat capacity) at constant pressure of exhaust gases	kJ / (kg · K)
h_{a1}	Specific enthalpy of air at temperature T_{a1} entering the compressor	kJ / kg
h_{a3}	Specific enthalpy of air at compressor discharge temperature T_{a3}	kJ / kg
h_{ae}	Specific enthalpy of air at temperature T_{ae} leaking from the control volume	kJ / kg
$h_{ct3.2}$	Specific enthalpy of the air flow from the external cooler at temperature $T_{ct3.2}$ entering the control volume	kJ / kg
$h_{ex,i}$	Specific enthalpy of air at temperature $T_{ex,i}$ extracted from the compressor extraction *i*	kJ / kg
h_{f4}	Specific enthalpy of fuel at temperature T_{f4} entering the heat source (combustion chamber)	kJ / kg
h_{g6}	Mean specific enthalpy of gases at temperature T_{g6} entering the turbine	kJ / kg
h_{g7}	Specific enthalpy of exhaust gases at temperature T_{g7}	kJ / kg
h_{g8}	Specific enthalpy of exhaust gases at temperature T_{g8}	kJ / kg
HR	Heat rate of the gas turbine, based on low heating value (LHV) of the fuel and electrical power output	kJ / kWh
HR_c	Corrected heat rate of the gas turbine	kJ / kWh
HR_m	Calculated from measured data heat rate of the gas turbine	kJ / kWh
h_{w4}	Specific enthalpy of the injected water or steam mass flow at temperature T_{w4} entering the control volume	kJ / kg
h_0	Specific enthalpy of the fuel at reference temperature T_{f0}=15 °C	kJ / kg
I_S	Secondary current at instrument transformer	A
K_I	Ratio of current transformer	-
K_U	Ratio of voltage transformer	-
$\dot{m}_{a1}$	Compressor inlet air mass flow	kg / s
$\dot{m}_{a3}$	Compressor discharge air mass flow	kg / s
$\dot{m}_{ae}$	Mass flow of sealing and/or leakage air leaving the control volume	kg / s
$\dot{m}_{CA,T}$	Total turbine cooling air mass flow	kg / s

Table 2 (*continued*)

Symbol	Definition	Unit
$\dot{m}_{CA,CC}$	Combustion chamber cooling air mass flow	kg / s
$\dot{m}_{CA,1stV}$	Cooling air mass flow for 1st turbine vane row	kg / s
$\dot{m}_{e3}$	Mass flow of extracted compressor discharge air	kg / s
$\dot{m}_{ct3}$	Air mass flow to the external cooler leaving and entering the control volume	kg / s
$\dot{m}_{d}$	Relative difference in inlet mass flow between the equivalent and the actual compressor (that is, equivalent reduction flow of actual compressor inlet air flow)	%
$\dot{m}_{eq}$	Air inlet mass flow of an equivalent compressor without cooling air extraction lines, but with the same power consumption as the actual compressor	kg / s
$\dot{m}_{ex,i}$	Extraction air mass flow at the compressor extraction line i	kg / s
$\dot{m}_{f4}$	Fuel mass flow entering the control volume	kg / s
$\dot{m}_{g6}$	Gas mass flow entering the turbine	kg / s
$\dot{m}_{g7}$	Mass flow of the turbine exhaust gases	kg / s
$\dot{m}_{g7c}$	Corrected mass flow of the turbine exhaust gases	kg / s
$\dot{m}_{g8}$	Mass flow of the turbine exhaust gases	kg / s
$\dot{m}_{w4}$	Injected water or steam mass flow entering the control volume	kg / s
n_{c}	Reference speed of the output shaft	1/s
n_{m}	Specified speed of the output shaft during the test	1/s
N	Number of correction factors	-
Pb	Cooling air booster power consumption	kW
P_{c}	Net shaft power output at reference conditions	kW
P_{COMP}	Compressor shaft power consumption	kW
P_{e9}	Electrical power output at generator terminals	kW
P_{e9c}	Corrected electrical power output at generator terminals	kW
P_{LL}	Transformer load losses	kW
P_{NLL}	Transformer no-load losses	kW
P_{S}	Net shaft gas turbine shaft power output during the test	kW
P_{TRL}	Transformer losses	kW
Q_{G}	Generator losses	kW
$Q_{G,d}$	Generator losses from design	kW
Q_{GB}	Gearbox losses	kW
Q_{a1}	Energy stream of compressor inlet air flow, at spec. enthalpy h_{a1}	kJ / s
Q_{a3}	Energy stream of air flow at combustion chamber inlet, at spec. enthalpy h_{a3}	kJ / s
Q_{ae}	Energy stream of sealing and/or leakage air flow leaving the control volume, at spec. enthalpy h_{ae}	kJ / s
$Q_{ct3.1}$	Energy stream of cooling air flow to cooler inlet, at spec. enthalpy h_{a3}	kJ / s
$Q_{ct3.2}$	Energy stream of cooling air flow from cooler outlet, at spec. enthalpy $h_{ct3,2}$	kJ / s
Q_{e3}	Energy stream of external air extraction flow, at spec. enthalpy h_{a3}	kJ / s
Q_{ex}	Energy stream of cooling air extraction equivalent flow expressed as $\dot{m}_{d}$, at spec. enthalpy h_{a1}	kJ / s

Table 2 (*continued*)

Symbol	Definition	Unit
Q_{f4}	Energy stream of fuel entering the combustion chamber, based on fuel low heating value (LHV)	kJ / s
Q_{g6}	Energy stream of turbine inlet flow, at spec. enthalpy h_{g6}	kJ / s
Q_{g7}	Energy stream of exhaust flow at turbine at spec. enthalpy h_{g7}	kJ / s
Q_{g8}	Energy stream of turbine exhaust flow at,spec. enthalpy h_{g8}	kJ / s
Q_{7Ta1}	Energy of turbine exhaust flow, with the reference temperature of its spec. enthalpy indexed to the reference ambient air temperature T_{a1}	kJ / s
Q_{7cTa1}	Corrected energy stream of turbine exhaust flow, with the reference temperature of its spec. enthalpy indexed to the reference ambient air temperature T_{a1}	kJ / s
Q_{7cT0}	Corrected energy stream of turbine exhaust flow, with the reference temperature of its spec. enthalpy indexed to the reference temperature T_0	kJ / s
Q_{lo}	Low heating value (LHV)(lower heating value) of the fuel at 15 °C and constant pressure	kJ / kg
Q_m	Gas turbine mechanical losses	kW
$Q_{m,d}$	Gas turbine mechanical losses from design	kW
Q_r	Radiation and convection heat losses of the whole surface	kW
Q_{th}	Thermal heat losses(for example: heat extracted from compressor air cooling system)	kW
$Q_{th,m(d)}$	Thermal heat losses, measured or from design	kW
Q_{w4}	Energy of injected steam/water flow, at spec. enthalpy h_{w4}	kJ / s
$Q_{w4,mc}$	Measured energy of injected steam/water flow, corrected to design if applicable	kJ / s
Q_{10}	Sum of engine losses ($Q_m+Q_G+Q_r+Q_{th}+Q_{GB}$)	kW
$SH=h_{f4}-h_0$	Sensible heat of the fuel	kJ / kg
S_m	Measured apparent power which is the product of measured (rms) voltage and (rms) current	kVA
S_r	Rated apparent power which is the product of rated (rms) voltage and (rms) current	kVA
T_0	Standard reference temperature for specific enthalpy of air and gases	K
T_{f0}	Reference temperature(=15°C) for specific enthalpy of fuel	°C
T_{a1}	Ambient air temperature	°C
T_{a3}	Air temperature at compressor discharge	°C
T_{ae}	Temperature of sealing and/or leakage air flow leaving the control volume	°C
T_c	Control temperature at reference conditions	°C
$T_{ct3.2}$	Temperature of the air flow from the external cooler entering the control volume	°C
$T_{ex,i}$	Extraction air temperature at the compressor extraction line *i*	°C
T_{f4}	Temperature of fuel entering the heat source (combustion chamber)	°C
T_{g6}	Temperature of gases entering the turbine	°C
T_{g7}	Average temperature of exhaust gases	°C
T_{g7c}	Corrected average temperature of exhaust gases	°C
T_{g7m}	Measured average temperature of exhaust gases	°C
T_{g8}	Mass flow average temperature of exhaust gases at the stack (simple cycle applications)	°C

Table 2 (*continued*)

Symbol	Definition	Unit
T_m	Control temperature during the test	°C
T_{w4}	Temperature of injected water or steam entering the control volume	°C
U_S	Secondary voltage at instrument transformer	V
η	Thermal efficiency of the gas turbine based on electrical power output and fuel lower heating value	-
η_C	Corrected thermal efficiency of the gas turbine	-
η_m	Measured/calculated thermal efficiency of the gas turbine	-
η_{tc}	Combustion chamber efficiency from design, taken into account the total radiation and convention heat losses	-
$\Delta_{TOT,i}$	Additive correction factor i for turbine outlet temperature	K
$\Delta_{TOT,i,a}$	Additive correction factor i for turbine outlet temperature, from measured to standard reference conditions	K
$\Delta_{TOT,i,b}$	Additive correction factor i for turbine outlet temperature, from specified to standard reference conditions	K
θ	Ratio of the absolute gas turbine compressor inlet air temperatures at test (measured), and at reference conditions	-
δ	Ratio of the ambient absolute pressure to the reference ambient absolute pressure	-

Note:
1. Air or gas temperatures are assumed to be total temperature unless otherwise agreed
2. The general equation of specific enthalpy of ideal gases is $h = h_T - h_{T0} \approx c_p(T-T_0)$

where

h_{T0} is the gas specific enthalpy at the standard reference temperature T_0 of the enthalpy and

T is the actual gas temperature.

Usually T_0=0°C : in this case h_{T0} = 0 and h = hT ≈ c_{pT}; but it can be assumed equal to the ambient air temperature, or to any other temperature.

6 Preparation for tests

6.1 General

Performance Testing requires complex and detailed preparations. Since the purpose of such tests may vary, it is important to establish upfront the test objectives, identify the participating parties and their role in the process. A clear determination of the equipment boundaries and associated instrumentation shall avoid any potential disagreements after the test. A detailed test procedure specific to the test site/supplier's test facility and conditions shall be agreed by all parties involved.

6.1.1 Agreements before the test

Many factors influence significantly the results of acceptance tests. Therefore tests shall always be carefully programmed, organized and conducted so that the results are of the highest practical accuracy.

6.1.2 Test objectives

The objective of any tests is to determine performance characteristics of the gas turbine in accordance to any previously drawn up agreements such as the Purchase Agreements, Test Criteria Documents, EPC requirements, Power Purchase Agreements, Contractual Services Agreement etc. A detailed procedure for conducting the tests and evaluating the results shall be issued and agreed upon prior to conducting the tests. This test procedure shall provide full details of the method of measurement and about method used for correcting the results from test conditions to the reference conditions or the criteria set out in the pertinent documents. This test standard does not deal with tests needed to determine the environmental emissions, noise and vibration, that generally form part of other test procedures. However, these tests can be carried out concurrently with acceptance tests as per the purchase contracts or other related documents.

6.1.3 Performance degradation

The performance degradation of gas turbine during operation is an existing phenomenon. The degradation on the gas turbine is caused primarily by fouling and erosion of the gas flow path, and also by wear and tear. The agreement to apply degradation corrections to the performance test results is strictly a commercial issue between the parties and beyond the scope of this standard.

In most cases, the gas turbine performance guarantees are made based on equipment “new and clean” condition. The contractual agreements between the parties should define the period when the equipment is considered as new and clean and state if performance corrections are permitted, when equipment is tested beyond this period.

The detailed methodology on how to apply degradation correction may be derived from Comparative Tests, fleet performance of similar units, predictive degradation curves, or other methods. It should be also noted that actual measurement of degradation through Comparative Testing over short time periods is difficult because the rate of deterioration and measurement uncertainty have similar magnitudes and by the fact that during commissioning the control parameters could be changed. The degradation correction may be additive or multiplicative and could be applied to the test results or the guarantees made to the gas turbine as indicated in 8.2.2.5.

6.1.4 Design, Construction and start up considerations

The following recommendations should be considered when establishing the requirements for instrumentation accuracy, calibration, documentation and location of permanent and temporary instrumentation to be used during the test.

1. If permanent installed instrumentation will be used during the test, the requirements of 6.4 should be implemented if possible at early stages of the design. The ability to conduct post test calibrations or to substitute with temporary instrumentation also should be considered.

2. For temporary instrumentation, the design should cater to allow connections and spools sections, pressure connections, thermo wells and electrical tie-ins. To meet the required flow meters measurement uncertainty limits, use of flow straighteners is recommended.

3. The instrumentation layout shall be as given in this scope for measurement uncertainty and if possible allow the ability to validate critical test measurements. (e.g. pressure, temperature, fuel flow, power output)

6.2 Test procedure

The performance test shall be conducted based on a test procedure, which was developed to provide detailed guidance on the test execution. This document supplements the contract obligations and clarifies particulars of contract issues. It shall provide the course of action for performing the test. . Prior to the execution, the test procedure shall be agreed upon, by authorized signatures of all parties to the test. The following topics should be included within the test procedure: