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Gas turbines — Acceptance tests

AMENDMENT 1: Acceptance tests for combined-cycle power plants

Turbines à gaz — Essais de réception

AMENDEMENT 1: Essai de réception pour des installations de puissance à cycle combiné

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.

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.

Amendment 1 to ISO 2314:1989 was prepared by Technical Committee ISO/TC 192, *Gas turbines.*

Annex A forms an integral part of ISO 2314.

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Gas turbines — Acceptance tests

AMENDMENT 1

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Add the following annex.

Annex A

(normative)

Acceptance tests for combined-cycle power plants

A.1 SCOPE

A.1.1 This annex specifies standard procedures and rules for the conduct and reporting of acceptance tests in order to determine and/or verify the power and the thermal efficiency of combined cycle power plants. It provides information on methods of measurement and on methods for correcting results obtained under test conditions to guaranteed or otherwise specified conditions.

A.1.2 The purpose of the acceptance test is to determine the performance of the combined cycle in relation to the guaranteed performances as:

a) power under specific operating conditions of the whole plant (gas and steam section) in a common contract or of the bottoming cycle only, if the gas turbine part was supplied under a separate contract.

b) thermal efficiency, heat rate or specific fuel consumption under specific operating conditions (only when contract for the total combined cycle)

A.1.3 This annex is applicable to unfired combined-cycle power plants. With suitable adjustments, it may also be used as a general guideline for combined-cycle plants with supplementary firing or other combined-cycle configurations.

The case where all components are part of different contracts is not considered here as it should be covered by corresponding pertinent standards to each equipment.

A.2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this annex. At the time of publication, the editions indicated were valid. All standards are subject of revision, and parties to agreements based on this annex are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 11086:1996, *Gas turbines — Vocabulary*

[1] To be published.

IEC 953-1:1990, *Rules for steam turbine thermal acceptance tests — Part 1: Method A — High accuracy for large condensing steam turbines*

IEC 953-2:1990, *Rules for steam turbine thermal acceptance tests — Part 2: Method B — Wide range of accuracy for various types and sizes of turbines*

A.3 CYCLE NOMENCLATURE

For relevant definitions, see ISO 3977-1 and ISO 11086.

Figure A.1 shows the basic nomenclature used in this annex. The station numbers refer to locations corresponding to mass or energy fluxes across the control surface.

The numbering is chosen so that all fluxes entering the same surface have the same number. The differentiation is made by using letters for the different fluids. Where the same fluid is crossing the same surface (different pressure levels for instance) an additional digit is used, for instance 10.1_S, 10.2_S for two steam pressure levels.

Stations 1 through 8 are identical to figure 1 of this International Standard.

Station 9 refers to the inlet to the heat recovery steam generator.
On the gas side (g) the additional digit is used to differentiate the heat exchange surfaces within the heat recovery steam generator (HRSG) if necessary.

Station 10 refers to the outlet of the HRSG.
The different steam pressure levels are characterized by the additional digit.

Station 11 refers to all inlets to the steam turbine.

Station 12 refers to all outlets of the steam turbine.

Station 13 refers to the inlets of the condenser.

Station 14 refers to the outlets of the condenser.

Station 15 refers to the inlets of the cooling tower.

Station 16 refers to the outlets of the cooling tower.

Station 17 refers to the inlets of the deaerator/feedwater tank.

Station 18 refers to the outlets of the deaerator/feedwater tank.

In addition to this nomenclature and to the designations in 3.2.4 of this International Standard, the following letters designate the type of fluid in the various part of the cycle:

s = steam
cw = cooling water
ca = cooling air
g = exhaust gas
w = water
a = air
f = fuel

A.4 TEST PROGRAMME

A.4.1 The acceptance tests shall normally be carried out immediately after the completion of the commissioning by the supplier and, in any event, not later than three months after the start of the demonstration period (reliability run) if any is negotiated, unless otherwise agreed by both parties. For a base load plant, the demonstration period may typically extend up to 30 days. In any case, before the tests, the plant shall be placed at the disposal of the manufacturer for examination and cleaning.

If the tests have to be delayed for any reason, agreement shall be made for consideration of degradation or fouling up to the test date

A.4.2 The following test activities should be scheduled.

a) Preparation for the tests
Any pipes, ducts or valves are to be set so as to produce conditions specified in the guarantee.

Dimensions and physical conditions of any part of the plant required for test purposes shall be determined and recorded prior to the test.

Installation and verification of the required calibrated instrumentation and data acquisition equipment for the test.

Isolation of the cycle organized and the adequate operation and control of the plant verified.

b) Preliminary test
A preliminary test shall be run for the purpose of

i) verifying whether the plant and related equipment are in suitable condition for the conduct of an acceptance test and satisfactorily operating at the specified load

ii) checking the instrumentation

iii) familiarization with the test procedure

After a preliminary test is made, it may, by agreement between the purchaser and the contractor, be deemed an acceptance test.

c) Performance tests to agreed procedure
d) Computation of results
e) Test report

A.5 OPERATING CONDITIONS FOR THE TEST

A.5.1 General

The provisions stipulated under 5.1 of this International Standard shall be extended accordingly to the entire combined-cycle plant. In particular special care is to be taken with regard to

a) load of the gas turbines
b) process steam extraction conditions

c) number of auxiliaries in service (pumps, etc.)
d) operating conditions of air cooled condenser or cooling tower (number of fans operating, speed, etc.)
e) settings and operating conditions of all controls.

For reasons of convenience the permissible deviations for test conditions from design or specified conditions according to IEC 953-2 are recalled in Table A.1.

Table A.1 Maximum deviation from specific conditions
(see also Table 2)

Variable	Maximum permissible deviation of test from that specified (IEC 953-2)
Steam extraction pressure (regulated)	± 5 %
Steam exhaust pressure	
- for back pressure turbines	± 5 %
- for condensing turbines	± 25 % if condenser is not included in the guarantee
Steam extraction flow rate	± 10 %
Cooling water flow	± 15 % if condenser is part of the supply
Cooling water inlet temperature	± 5 K if condenser is part of the suppl y

Reasonable effort shall be devoted to ascertain that these deviation ranges are respected. If, in spite of this, no success can be achieved, agreement has to be made on additional uncertainties of the results and whether the tests should proceed.

A.5.2 Operating conditions

Prior to any readings, the plant operation shall be stabilized at a constant load.

Stability will be achieved when continuous monitoring indicates that readings have been within the maximum permissible fluctuations for a period of time which shall be agreed upon by the parties to the test.

The measurement period shall take one hour, divided typically into three reading sets.

The maximum permissible fluctuations are half the permissible deviations given in Table A.1 except for the output which may vary by ± 3 %

A.6 INSTRUMENTS AND METHODS OF MEASUREMENT

A.6.1 General

This clause describes the type, the methods of measurement and the precautions to be taken at the different stations behind the gas turbine as defined in figure A.1.

The extent and the quality (accuracy) of the measurements may be influenced greatly depending on the scope of supply and the division of work.

Measurements within one scope of supply are made essentially for a check of the operation conditions and therefore may be performed in a more simple manner.

Measurements for stations at limit of supply are, on the other hand, needed for verification of contractual performance and need great care and accuracy.

A.6.2 Measurements at Station 9

A.6.2.1 Gas-side measurements

This station defines the energy input to the heat recovery steam generator in terms of gas mass flow, gas analysis and gas temperature.

The exhaust gas mass flow of large size gas turbines in general cannot yet be measured directly with sufficient accuracy, however, in most cases it can be determined with sufficient accuracy either:

- by carrying out a careful heat balance calculation around the gas turbine (see 8.5 of this International Standard) or
- by carrying out a heat balance over the heat recovery steam generator using the gas temperature measurements at Stations 9 and 10 and additional accurate measurements of feedwater flow and water/steam temperatures and pressures.

For detailed analysis of performance figures or when the sensors for the exhaust gas temperature are to be located where velocity and temperature are not homogenous, the exhaust gas mass flow may be determined from measurements of the energy distribution in the exhaust duct section (see A.8.1.2).

Special attention shall be paid to ensure sufficient pressure, temperature and velocity measurements for a true picture of the mass averaged gas temperature in the exhaust duct.

Alternatively the gas analysis for an unfired heat recovery steam generator may be measured at station 10 g, where the temperature level does not require special equipment.

Additionally the pressure loss across the heat recovery steam generator may be verified by use of station 10 g static pressure.

Intermediate temperature measurements along the HRSG may be made for verification purposes when multi-pressure cycles are considered.

These optional temperature measurements are intended to help verify the steam generator internal heat and mass balances

A.6.2.2 Water-side measurements

In order to define the heat and the mass balances of the heat recovery steam generator, the feed water mass flow and the feedwater temperature shall be measured.

When separate feedwater pumps are used for each pressure level, corresponding measurements shall be made on each line.

A.6.3 Measurements at Station 10

A.6.3.1 Gas-side measurements

The energy at the outlet of the HRSG is defined at this station for use in heat balance calculations of the heat recovery steam generator. Besides temperature measurements, gas analysis can be measured here for convenience as stated in A.6.2.

NOTE: Optional measurements at Station 10 may be made for the same purpose as the measurements at Station 9.

A.6.3.2 Steam-side measurements

The steam parameters - especially pressure, temperature, mass flow - are measured here. Station 10 has to be defined for each pressure level where steam leaves the steam generator to the steam turbine or for heating purpose.

If no feedwater is diverted or recirculated, the feedwater mass flow measurements shall be taken (because of the higher accuracy), in preference to steam flow measurements.

Any spray water injection used to control the final steam temperature can be determined by carrying out a heat balance around the attemperator using measurements of steam and water temperatures, pressures and feed flow.

A.6.4 Measurements at Station 11

Measurements at Station 11 define the steam flow to the steam turbine and the steam conditions.

A.6.5 Measurements at Station 12

Measurements at Station 12 are intended to define the steam flow delivered by the steam cycle for any external process use and/or for NO_x reduction in the gas turbine combustion chamber. In addition the energy level (pressure, temperature) at which this transfer occurs is defined:

Measurements at the exhaust of the steam turbine are usually only for internal check purposes since the condenser station is the preferred station

A.6.6 Measurements at Station 13

The cooling water flow is to be derived or measured and the inlet temperature is to be measured at this station.

The cooling water flow rate is not normally measured. It is derived by heat balance calculations around the steam turbine and condenser.

The cooling water flow needs only to be measured or derived from calculation when separate performance verification for the steam turbine, the condenser or the cooling tower are required.

This is the case when these components are provided by different suppliers.

In the case of an air cooled condenser, the ambient air temperature is to be measured here.

The make-up water is preferably brought into the condenser when limited process steam amounts are to be delivered. This is the normal location for cycles with no process steam supply.

A.6.7 Measurements at Station 14

The cooling water outlet temperature is measured at this station.

The condition of the main condensate is measured at this station.

When an air cooled condenser is considered, the temperature of the air leaving the condenser is measured here.

All these measurements are made for verification purposes only.

A.6.8 Measurements at Station 15

The conditions of the cooling water and the air entering the cooling tower are defined at this station. The air temperature and humidity are important parameters when guarantee includes the performance of the cooling tower.

A.6.9 Measurements at Station 16

The conditions of the air and the cooling water leaving the cooling tower are measured here.

All these measurements are for verification purposes only.

A.6.10 Measurements at Station 17

When large amounts of make-up water are required (process steam extraction, NO_x steam or hot water injection into the gas turbine) the mass balance of the system is usually carried out at the feedwater tank station.

Since heating steam is involved, make-up water temperature has to be measured. Where the extraction steam is entirely lost, the make-up water flow does not need to be measured since it corresponds to the extraction flow, which does have to be measured.

A.6.11 Measurements at Station 18

The hot water extraction flow and condition is measured at this station. Hot water may be used for injection into the combustion chamber, for fuel preheating, for the fuel treatment plant or some other purpose.

A.7 TEST METHODS

A.7.1 General

The description of the test procedure is flexibly structured based on phased testing to allow application of this standard to determine plant performance in the various combined cycle applications, for instance phased construction, retrofit, etc.

The following test phases are considered.

Phase I: Simple-cycle performance test of the gas turbine using the bypass stack, if available.

Phase II: Combined-cycle performance test of the whole plant.

For combined-cycle plants with no provision for simple-cycle operation without the bottoming cycle, Phase I and Phase II are performed concurrently.

A.7.2 Phase I test (simple-cycle mode)

This test demonstrates gas turbine plant power and thermal efficiency for comparison to guarantee values.

The Phase I test shall be conducted according to the rules set in the main part of this International Standard.

Air flow reference data are calculated from the test data or set by appropriate measurement for use in determining change of gas turbine compressor air flow between Phase I and Phase II.

A.7.3 Phase II test (combined-cycle mode)

The Phase II test shall be performed while the bottoming cycle of the combined cycle is in a new and clean condition. The test shall be conducted when the combined-cycle plant and all test instrumentation are functioning satisfactorily and in a steady-state condition.

The Phase II test results combined with those of the Phase I test demonstrate the total combined-cycle plant power and thermal efficiency for comparison to guarantee values, whereby the different boundary conditions (GT exhaust mass flow, temperature and pressure) are taken into account.

The HRSG and the whole steam cycle shall be isolated in such a way that uncontrolled (not quantified) steam and water losses can be avoided. The HRSG is operated with zero blow-down.

A.8 COMPUTATION OF RESULTS

A.8.1 Calculation of measurement-derived data

Several data which have to be defined at different stations are not directly measured but have to be derived and calculated from other measurements.

The calculation methods are defined here in order to ensure a common understanding.