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Gas turbines — Procurement —

Part 8: Inspection, testing, installation and commissioning

Turbines à gaz — Spécifications pour l'acquisition —

Partie 8: Contrôle, essais, installation et mise en service

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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 3977-8 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 and definitions*

— *Part 2: Standard reference conditions and ratings*

— *Part 3: Design requirements*

— *Part 4: Fuels and environment*

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

— *Part 7: Technical information*

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

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

Gas turbines — Procurement —

Part 8:
Inspection, testing, installation and commissioning

1 Scope

This part of ISO 3977 states the principles for systems and procedures to assure the integrity of a packager's product and services.

It gives guidance on the inspection, testing, installation and commissioning required for the package and packaged equipment. It outlines the responsibilities between the purchaser and packager for inspection, coordination, reporting and recording.

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 2314:1989, *Gas turbines — Acceptance tests*

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

ISO 3997-2:1997, *Gas turbines — Procurement — Part 2: Standard reference conditions and ratings*

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

ISO 3997-4:2002, *Gas turbines — Procurement — Part 4: Fuels and environment*

ISO 4406:1999, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

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

ISO 10442:—[1)] , *Petroleum, chemical and gas service industries — Packaged, integrally geared centrifugal air compressors for general refinery service*

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

ISO 11086:1996, *Gas turbines — Vocabulary*

1) To be published.

ISO 13709:—[1)], *Centrifugal pumps for petroleum, petrochemical, and natural gas industries*

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

IEC 60034-1:1983, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60034-4:1985; *Rotating electrical machines — Part 4: Methods for determining synchronous machine quantities from tests*

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 3977-4 and ISO 11086 and the following apply.

3.1
inspection
process by which it is demonstrated that materials, components, assemblies or complete packages satisfy one or more particular specification requirements of the packager or purchaser

NOTE This may include verificational documentation, reports, material certificates, chemical analyses, physical or dimensional checks, build records, visual checks and/or results of documented inspections and tests including any other non-destructive evaluation (NDE) methods or techniques that may be employed.

3.2
test
process by which it is demonstrated that assemblies, completed components or packages satisfy the physical, functional and operational requirements as specified by the packager's test schedules and procedures, or the purchaser's specification

3.3
witnessed
term meaning that a hold is applied to the production schedule and that the inspection or test will be carried out with the purchaser or his representative in attendance

3.4
observed
term meaning that the purchaser will be notified of the timing of the inspection or test

NOTE However, the inspection or test should be performed as scheduled, and if the purchaser or his representative is not present, the packager should proceed to the next step.

4 General principles

The packager shall furnish the purchaser with inspection and testing plans. These define the actions required by the packager and his sub-suppliers to assure the integrity of the package.

These plans should include any specific requirements stated by the purchaser in his enquiry and any local or national regulations applicable to the package in either the country of origin or destination. The plan shall be agreed between the packager and purchaser, and any third-party inspector who may be appointed by the purchaser, prior to commencement of manufacture.

It is the purchaser's responsibility to notify the packager of any applicable local and national regulations in the country of destination.

Where inspection and testing have to be done on site, these shall be identified in the inspection and testing plans and agreed between the packager and purchaser.

The packager and purchaser shall agree to the following:

— the extent of purchaser participation in the inspection and testing, including witnessed and observed test points;

— detail running test procedures and acceptance parameters and criteria;

— notification period for hold points and witnessed tests and observed tests;

— facilities and services to be provided by the purchaser.

The packager shall keep at least the following data available for a minimum of 10 years after the date of commissioning for examination by the purchaser or his representative upon request:

— certification of materials;

— purchase specifications for all items on bills of materials;

— test data to verify that the requirements of the specification have been met;

— results of documented material inspections, including fully identified records of all heat treatment and radiography processes;

— when specified, final-assembly maintenance and as-built clearances.

In addition to the above requirements, the purchaser may specify the following:

— parts that shall be subjected to surface and subsurface examination;

— the type of non-destructive evaluation to be applied.

5 Inspection

5.1 General

Inspection activities are carried out throughout the entire manufacturing process and may cover

— materials,

— components,

— fabrications,

— sub-assemblies,

— auxillary packages, and

— finished gas turbine packages.

Where inspection activities involve pressure-containing parts, these shall not be painted until the specified inspection of the parts is completed.

5.2 Material inspection

Non-destructive evaluation (NDE) procedures and acceptance criteria used in the manufacturing and assembly procedures for the gas generator, power turbine and all other items of equipment shall be in accordance with the agreed inspection and testing plans.

5.3 Mechanical inspection

During assembly and prior to functional/operational testing, components or sub-assemblies (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another appropriate method to remove foreign materials, corrosion products and mill scale.

Any portion of the oil system furnished shall meet the cleanliness requirements of ISO 4406.

When specified, the purchaser may inspect the equipment and all piping and appurtenances furnished by or through the packager for cleanliness before heads are welded to vessels, openings in vessels or exchangers are closed, or piping is finally assembled.

When specified, the hardness of parts, welds and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds or zones. The method, extent, documentation and witnessing of the testing shall be mutually agreed upon by the purchaser and packager.

6 Testing

6.1 General

This clause deals with the minimum recommended requirements for the physical testing of components, assemblies and the complete package prior to entry into commercial service.

The purchaser and packager shall agree on the scope of testing. This may include a selection of optional tests specified by the purchaser as described in 6.4.

Figure 1 shows the desired sequence of mandatory and optional operation testing and may be used for guidance.

All test reports shall be retained for periods consistent with the requirements of ISO 3977-2.

6.2 Hydrostatic test

As a minimum, components defined by legislation or national standards as pressure vessels (excluding the casings of gas generator and power turbine) shall be tested hydrostatically according to legislation or national standards, but at least with liquid at a minimum of 1,5 times the maximum allowable working pressure but not less than 140 kPa differential pressure. Other components and systems shall be tested in accordance with the purchaser's requirements or statuatory or mandatory requirements applicable to the destination territory. The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

If the part tested is to operate at a temperature at which the tensile strength of a material is below the tensile strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The data sheets shall list actual hydrostatic test pressures and temperatures.

The chloride content of liquids used to test austenitic stainless-steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 30 min. Large, heavy castings may require a longer testing period which is to be agreed upon by the purchaser and packager.

Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

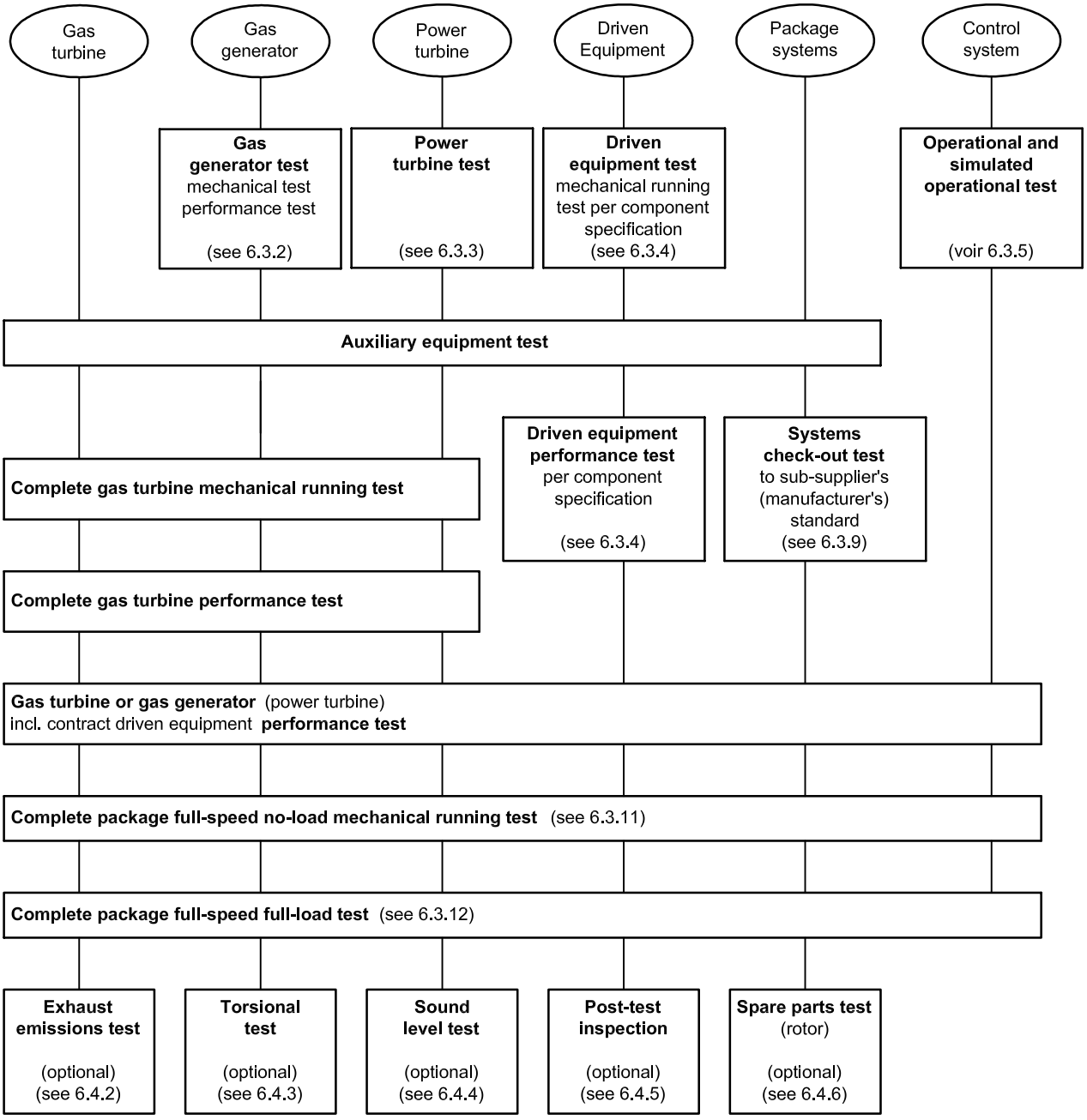

Figure 1 — Diagram of options for testing

6.3 Functional/operating tests

6.3.1 General

Figure 1 shows a visual representation of the alternative testing options.

The extent of testing possible prior to delivery to site will depend upon the design, rating and size of gas turbine and the facilities available at the packager's works. Where these factors prohibit shop testing, the package shall be tested at an alternative location or on site. In any case, site acceptance tests are usually required irrespective of the extent of works testing.

The extent and location of testing shall be agreed between the purchaser and packager. Gas turbine and gas generator performance tests shall be in accordance with ISO 2314. The following are examples of the tests which are commonly performed:

— gas turbine tests;

— gas turbine with the contract driven equipment;

— complete package test.

For gas turbines with a free power turbine, the following alternative tests may be performed:

— gas generator tests;

— free power turbine test.

These tests may be performed at no load, part load or full load. For mechanical drive applications, the driver may be used to execute full pressure, full load or full speed tests of the driven equipment.

The tests shall include, as appropriate,

— cold start,

— hot start,

— full range operation of variable inlet guide vanes and/or stator stages,

— operation of bleed valves, and

— operation of anti-icing systems (when they are furnished).

All lubricating oil pressures, viscosities and temperatures shall be within the range of operating values recommended in the packager's operating instructions for the specific unit being tested.

The casings, lube oil system, fuel system and hydraulic system shall be checked for joint and connection tightness. All oil and fuel leaks shall be corrected. Air leaks adversely affecting performance and, in the judgement of the purchaser, causing a safety hazard shall be corrected.

All warning, protective and control devices shall be adjusted and tested for satisfactory operation. When tests are to be witnessed by the purchaser, only a random selection shall be chosen for demonstration during the test.

6.3.2 Gas generator

The gas generator shall be tested either as an individual assembly or as a component part of the assembled gas turbine. The test shall demonstrate mechanical running, power and thermal efficiency in accordance with the manufacturer's specifications.

This test may be conducted using slave test bay equipment (i.e. controls, ducting, air filtration, dynamometer, nozzles, etc.), however, this shall be identified in the test procedures as supplied by the packager and approved by the purchaser.

During the gas generator mechanical running and/or performance test, the mechanical operation of all contract equipment and safety devices that can be tested shall be satisfactorily demonstrated. Vibration readings shall not exceed the limits given in 6.7.2.1 of ISO 3977-3:2002. The performance of the machine shall meet the criteria specified.

6.3.3 Power turbine

Where a power turbine is tested separately (i.e. not directly coupled to the gas generator, see also 6.3.2), it shall be tested for compliance with respect to vibration levels and the satisfactory operation of the fitted protection devices and instrumentation.

6.3.4 Driven equipment

6.3.4.1 Electrical generator test

The electrical generator shall be tested at the generator vendor's manufacturing facility in accordance with IEC 60034-1 and IEC 60034-4.

The generator shall be load performance tested with the package coincidental with the turbine/load equipment train mechanical run test at a location to be agreed

6.3.4.2 Compressor test

Compressors for the oil, gas, petrochemical and refining industries shall be shop tested in accordance with the requirements of ISO 10442.

Optional tests within ISO 10442 may form part of the package shop tests.

6.3.4.3 Pump test

Pumps for the oil, gas, petrochemical and refining industries shall be tested in accordance with the requirements of ISO 13709.

Optional tests within ISO 13709 may form part of the package shop tests.

6.3.4.4 Load gear test

Main load gears for the oil, gas, petrochemical and refining industries shall be tested in accordance with the requirements of ISO 13691.

6.3.5 Control system

The contract control panel shall be fully hardware operational tested. A functional test shall also be performed, either as a type test or as a contract specific test on the contract control panel, as agreed between the purchaser and packager. The functional test shall be carried out against a simulator, or the packager shall fully check the operation of all gas turbine operating parameters prior to the installation and commissioning phase.

6.3.6 Auxiliary equipment tests

When specified, auxiliary equipment as listed in 5.2 of ISO 3977-3:2002 shall be tested prior to the mechanical running test. Details of the auxiliary equipment tests shall be developed jointly by the purchaser and packager.

6.3.7 Gas generator/power turbine mechanical test

When specified, a separable gas generator and power turbine shall be mechanically tested together. Testing shall be in accordance with 6.3.2. The mechanical condition of power turbines shall comply with the vibration and balancing requirements of 4.7.2 of ISO 3977-3:2002. For power turbines with hydrodynamic bearings, oil temperatures and bearing temperatures shall comply with the packager's specifications.

6.3.8 Gas generator/power turbine performance test

The gas turbine power and thermal efficiency test shall be carried out in accordance with ISO 2314 and/or as agreed by the purchaser and packager.

6.3.9 Systems check-out

All on-package and off-package components and systems shall be tested in accordance with the manufacturers' standards and established procedures. These tests shall confirm the integrity of the systems and their ability to function correctly, and may include as appropriate, some or all of the following:

— visual inspection;

— loop checks;

— pipework flushing;

— pressure testing or leak testing;

— instrument set points;

— valve sequencing.

6.3.10 Gas turbine including contract driven equipment

Testing of the complete gas turbine (gas generator and power turbine) including contract driven equipment shall take place prior to entry into commercial operation and may take place either at the packager's facility or on site after installation and commisioning, but in any event shall be in accordance with agreed testing procedures.

6.3.11 Full-speed no-load (FSNL) test

6.3.11.1 FSNL test preparation

Test preparation in accordance with this subclause shall be performed before the FSNL test is performed at the packager's facility or, if agreed, on site.

The contract bearings and, where practical, the contract shaft seals shall be used in the package for the mechanical running test.

All lubricating oil pressures, viscosities and temperatures shall be within the range of operating values recommended in the packager's operating instructions for the specific unit being tested.

Where slave test-stand oil filtration is used, it shall be 10 μm nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 4406 before any test is started.

All joints and connections shall be checked for tightness, and any leaks shall be corrected.

All warning, protective and control devices shall be checked, and adjustments made as required.

For mechanical drive applications, facilities shall be installed to prevent the entrance of oil or other debris into the driven unit during the mechanical running test. These facilities shall be in operation throughout the test.

Testing with the contract coupling(s) is required when the driven unit is connected. After the running tests, the shrink fit of hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub(s) have not moved on the shaft during the tests.

All contract vibration probes, cables, oscillator-demodulators and/or accelerometers shall be in use during the test.

Wherever possible, shop test facilities shall include instrumentation with the capability of continuously monitoring, plotting and recording revolutions per minute, peak-to-peak displacement, peak acceleration, r.m.s. velocity and phase angle. All vibration data shall be presented as agreed upon.

When vibration acceptance criteria are identified in terms of seismic values, these shall be stated in the test procedures and actual values recorded using the contract instrumentation during the test.

6.3.11.2 Speed control

For electrical drive applications, the speed control equipment shall be demonstrated over the agreed governor range. For mechanical drive applications, the equipment shall (where permissible) be operated at speed increments of approximately 10 % from minimum governor setting to the maximum continuous speed. In either case, equipment shall run at the normal maximum continuous speed until bearings, lube-oil temperatures and vibrations have stabilized.

The output speed shall be increased in accordance with the packager's recommendations to demonstrate satisfactory operation of the unit at speeds within 3 % of the set trip speed for a maximum duration of 15 min.

Overspeed trip devices shall be checked and adjusted until a value within 1 % of the nominal trip setting is attained.

The speed governor and any other speed-regulating devices shall be tested for smooth performance over the operating speed range. No-load stability and response to the control signal shall be checked.

The speed shall be reduced to the maximum continuous speed, and the equipment shall be run for 4 h, or less if agreed.

Caution should be exercised when operating at or near critical speeds.

6.3.11.3 Test operation

During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured vibration levels of each component shall not exceed the specified limits and shall be recorded throughout the operating speed range.

While the equipment is operating at maximum continuous speed and at other speeds that may have been specified in the test procedure, frequency spectrum analysis shall be made to demonstrate vibration amplitudes at frequencies other than synchronous. As a minimum, these shall cover the range from 0,25 to 8 times the maximum continuous running frequency. If the amplitude of any discrete, non-synchronous vibration exceeds 20 % of the specified vibration levels, the purchaser and packager shall mutually agree if any additional testing is needed or the equipment is suitable for shipment.

When specified for flexible-shaft machines, the mechanical running test shall verify that the gas turbine lateral critical speeds conform to the requirements of ISO 3977-3:—, subclause 4.7.3 and annex B. The first lateral critical speed determined during the mechanical running test should preferably be indicated on the nameplate followed by the word “test”. When the first critical speed cannot be determined due to damping, the calculated critical speed should preferably be indicated on the nameplate followed by the word “calculated”.

When specified, recordings shall be made of all real-time vibration data.

6.3.11.4 Final test

If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test shall not be acceptable, and the final tests shall be run after remedial work.

6.3.12 Full-pressure/full-load/full-speed test

The details of the full-pressure/full-load/full-speed test shall be agreed by the purchaser and packager. This test may be substituted for the mechanical running test.

6.4 Optional tests

6.4.1 General

When specified, the optional tests selected from 6.4.2 to 6.4.7 shall be performed, depending on the facilities, either in the shop or on site as mutually agreed between the packager and purchaser.

6.4.2 Exhaust emissions test

Exhaust emissions test shall be carried out in accordance with ISO 11042-1.

6.4.3 Torsional test

Torsional vibration measurements shall be made to verify the complete power train torsional analysis. The test procedure shall be mutually agreed between purchaser and packager.

NOTE Torsional tests are very complex and require a highly sophisticated test setup.

6.4.4 Sound-level test

The sound-level test shall be performed in accordance with ISO 6190 or a procedure as agreed between the packager and purchaser.

6.4.5 Post-test inspection

Borescopic inspection and/or dismantling inspection and reassembly of the major driven equipment, gears and the driver may be made after satisfactory completion of the mechanical running test. The packager and purchaser shall agree to what extent the package equipment shall be dismantled and inspected.

6.4.6 Spare-rotor test

Spare rotors shall be tested as specified by the purchaser

6.4.7 Endurance test

Prolonged running (24 h or more) may be specified by the purchaser. The objectives and acceptance criteria of this running shall be agreed between the packager and purchaser.

NOTE Usually, but not exclusively, these tests are required to demonstrate an agreed minimum reliability of the package or a particular component or system.

7 Preparation for storage and shipment

7.1 General

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

Where required, preservation shall make the equipment suitable for 6 months of outdoor storage with no disassembly after that period. If storage for a longer period is specified, the purchaser shall consult with the packager regarding the recommended procedures to be followed.

The purchaser shall inform the packager about the storage facilities on site. The packager shall provide the purchaser with the instructions necessary to assure the integrity of the storage preservation after the equipment arrives at the job site and before start-up.

The packager shall inform the purchaser of any precautions that need to be considered to avoid compromising the health and safety of personnel or the mechanical integrity of the equipment.

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

7.2 Preparation

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

Unless otherwise specified, exterior surfaces, except for machined and/or corrosion resistant surfaces, shall be painted with a primer coat and at least one finish coat.

Exterior machined surfaces shall be coated with a suitable corrosion inhibitor.

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

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

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

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

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

The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with the item and serial number of the equipment for which it is intended. In addition, equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

Auxiliary piping connections on the purchased equipment shall be permanently identified to agree with the packager's connection table or general arrangement drawing.

If vapour-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags shall be attached to an accessible area for ease of removal. Where applicable, bags may be installed in wire cages attached to flanged covers, and bag locations shall be indicated by corrosion-resistant tags.

One copy of the packager's standard installation instructions shall be packed and shipped with the equipment.

8 Installation and commissioning

Prior to the equipment arriving at the site, the purchaser and packager shall agree upon the installation and commissioning programme for the equipment to be installed.

The purchaser shall inform the packager of any limitations (such as working hours, access restrictions, etc.) applicable to the installation site which may have an input on the programme.

Matters related to the coordination and interfacing of all site-related activities shall be adressed by the purchaser and packager.

The purchaser shall inform the packager what services and/or utilities are available at the site prior to the installation and commissioning phase of the project.

The packager shall be responsible for the provision of all installation and commissioning procedures for equipment/services within his scope of supply.

Equipment shall be installed in accordance with the packager's procedure, which may be in the form of installation manuals, check list(s) or similar.

These activities shall be logged for record purposes and retained for future reference. These procedures may include, amongst others, some or all of the following activities:

— mechanical installation;

— electrical installation;

— functional testing of controls;

— phase sequence checks of motors and generators;

— installation testing of electrical equipment;

— continuity checks of wiring;

— loop testing of control and/or instrument circuits;

— flushing of pipework;

— leak testing of pipework under pressure;

— alignment;

— grouting;

— pre-commissioning checks;

— testing of emergency facilities and systems.

If not contained as a section within the installation manual, the packager may elect to have a separate manual for the sole purpose of successful commissioning of the equipment.

Unless otherwise agreed, the purchaser shall be responsible for ensuring that adequate utilities (i.e. compressed air and/or instrument quality air, fuel, water, power, etc.) are available during comissioning and that adequate load for the driven unit is available when site acceptance testing or endurance runs occur.

In the event that site acceptance tests and/or endurance runs are interrupted by circumstances beyond the control of the packager, then the tests shall recommence and continue, after the problem has been rectified and normal conditions restored, as if the interruption had not occurred.

ICS 27.040

Price based on 12 pages