INTERNATIONAL STANDARD

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Gas turbines — Procurement —

Part 9: Reliability, availability, maintainability and safety

Turbines à gaz — Spécifications pour l'acquisition —

Partie 9: Fiabilité, disponibilité, maintenabilité et sécurité

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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.

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.

International Standard ISO 3977-9 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: Gas turbine applications*

— *Part 6: Combined cycles*

— *Part 7: Technical information*

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

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

Gas turbines — Procurement —

Part 9:
Reliability, availability, maintainability and safety

1 Scope

The purpose of this part of ISO 3977 is to provide a basis for exchange of information about reliability, availability, maintainability and safety between gas turbine manufacturers, users, consultants, regulatory bodies, insurance companies and others. It defines terms and definitions used within this part of ISO 3977 and also describes component life expectancy, repairs and criteria for determining overhaul intervals.

This part of ISO 3977 is applicable to all elements of the gas turbine, especially, but not limited to, the following:

— compressor

— turbine

— combustion system

— intercooler

— regenerator or recuperator

— air ducting system

— exhaust ducting system

— air intake system

— control system

— fuel system

— lubrication system

— cooling water system

— rotor bearings

— gears

— coupling

— starting equipment

— baseplate/foundation

— enclosures and ventilation system.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 3977. For dated references, subsequent amendments to, or revisions of, this publication 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 edition of the normative document 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.*

3 Terms and definitions

For the purposes of this part of ISO 3977, the following terms and definitions apply.

3.1
actual unit starts
AUS
number of times the unit was actually synchronized or run from the shut-down situation up to the required speed

3.2
age
actual number of calendar years the unit has been in commercial service

3.3
ageing
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 It is normally the result of increased seal clearances due to vibration and wear, loss of profile and increased blade surface roughness due to corrosion, erosion, etc.

3.4
attempted unit starts
number of attempts to synchronize the unit or run up to the required speed after being shut down

NOTE Repeated failures to start for the same cause within the allowable specified starting time period, without attempting corrective action, are considered a single attempt.

3.5
available
state in which a unit is capable of providing service, whether or not it is actually in service, regardless of the capacity level that can be provided

3.6
available hours
AH
time, in hours, during which the unit is available for service

3.7
availability factor
AF
probability that a unit, major equipment or component will be usable at a point in time, based on the past experience with that specific gas turbine:

$$\mathrm{AF} = 1 - \frac{\mathrm{FOH} + \mathrm{POH}}{\mathrm{PH}} = \frac{\mathrm{AH}}{\mathrm{PH}}$$

where

FOH is forced outage hours

POH is planned outage hours

PH is period hours

3.8
availability rate
AR

$$AR = \frac{SH}{SH + OH}$$

where

SH is service hours

OH is outage hours

3.9
average run time
ART

$$ART = \frac{SH}{AUS}$$

3.10
base load rated output
normally expected or guaranteed output of the gas turbine when operating at the specified conditions and at the base-rated turbine temperature level (or other limit imposed by the manufacturer) and in a new and clean condition

3.11
chemical vapour deposition
CVD
method of producing a coating, based on a chemical reaction between a gaseous phase of the coating material and the heated surface of the substrate

NOTE See coating (3.13).

3.12
chromizing
coating by a chromium overlay

NOTE Also known as chromating [see coating (3.13)].

3.13
coating
in general, a consumable and generally replaceable overlay provided to protect the base material against corrosion and/or erosion

EXAMPLE The following are types of coatings which may be provided:

— chemical vapour deposition (CVD)

— chromizing

— diffusion chromizing

— physical vapour deposition (PVD)

— plasma spray

— atmospheric plasma spray (APS)

— vacuum plasma spray (VPS).

3.14
cold testing
all functional tests conducted on the installation site up to and including cranking the gas turbine by means of the starter but before firing the gas turbine

3.15
compressor surge
unstable condition characterized by low-frequency fluctuations in mass flow of the working fluid in the compressor and in the connecting ducts

3.16
condition monitoring
assessment of the condition of a gas turbine or its components by measuring those parameters which, over time, have been established to correlate with an incipient failure condition, and where the monitoring action is non-intrusive with respect to the equipment

NOTE Any subsequent maintenance activity which is based upon a diagnosis of parts condition over time and executed in accordance with the monitored degree of deterioration, is referred to as "on-condition maintenance".

3.17
corrosion
chemical reaction and change of the gas turbine material due to corrosive elements in the working fluid

3.18
damage
sudden unforseen physical loss of the ability of a component or equipment to fulfil a required function

3.19
design life
usable operating life for which a component or equipment has been designed, including a safety margin against failure

NOTE Where routine repairs are designed to sustain component life, such as recoating, crack repairs, etc., the design life is the total life beyond which repairs are no longer feasible.

3.20
diffusion chromizing
enrichment of base metal with chromium by a diffusion process to increase the hot corrosion resistance

NOTE See coating (3.13).

3.21
emergency start
start of a gas turbine in any emergency with the objective of producing power in the shortest possible time, without the realms of the gas turbine operating possibilities

3.22
emergency shut down
ESD
shut down of a gas turbine in an emergency with the objective of taking the machine out of operation in the shortest possible time

3.23
equivalent availability factor
EAF

$$\mathrm{EAF} = \frac{\mathrm{PH} - (\mathrm{EUDH} + \mathrm{EPDH} + \mathrm{ESEDH})}{\mathrm{PH}} \times 100\ \%$$

3.24
equivalent forced derated hours
EFDH
product of the forced derated hours (FDH) and the size of hours reduction, divided by the net maximum capacity (NMC)

3.25
equivalent forced derated hours during reserve shutdowns
EFDHRS
output reduction factor given by the ratio of output reduction and net maximum capacity (NMC)

3.26
equivalent operating hours
T_{eq}
weighted operating events affecting the life of the machine forming an equivalent operating time to determine inspection intervals or life expectancy

EXAMPLE

$$T_{eq} = a_1 n_1 + a_2 n_2 + \sum_{i=1}^{n} t_i + f \times w \times \left(b_1 t_1 + b_2 t_2\right)$$

where

a_1 is the weighting factor for each start;

n_1 is the number of fired starts;

a_2 is the weighting factor for fast loading;

n_2 is the number of fast loadings;

t_i is the equivalent operation hours for rapid temperature changes, e.g. due to step load changes or load rejections;

n is the number of rapid temperature changes;

t_1 is the operating hours with output up to base-load rating;

b_1 is the weighting factor for base-load duty;

t_2 is the operating hours with output between base- and peak-load ratings;

b_2 is the weighting factor for peak-load duty;

f is the weighting factor for contaminated, out of specification or non-specifiable fuels;

w is the weighting factor for injected water or steam;

NOTE Other factors can be considered.

3.27
equivalent planned derated hours
EPDH
product of the planned derated hours (PDH) and the size of reduction, divided by the net maximum capacity (NMC)

3.28
equivalent scheduled derated hours
ESDH
product of the scheduled derated hours (SDH) and the size of reduction, divided by the net maximum capacity (NMC)

3.29
equivalent seasonal derated hours
ESEDH
net maximum capacity (NMC) minus the net dependable capacity derated hours (NDC), multiplied by the available hours (AH) and divided by the net maximum capacity (NMC)

3.30
equivalent unplanned derated hours
EUDH
product of the unplanned derated hours (UDH) and the size of reduction, divided by the net maximum capacity (NMC)

unplanned = forced + maintenance (NERC)

3.31
erosion
abrasive wear of material by mechanical impact of solid particles in the working fluid

3.32
fired start
any start which achieves full ignition and applies heat to the gas path components

NOTE For fired hours, see service hours (3.98).

3.33
failure
sudden and unexpected ending of the ability of a component or equipment to fulfil its function

3.34
failure to start
FS
inability to bring a unit through a qualifying starting attempt to the in-service state within a specified period due to equipment supplied in the contract

NOTE 1 Repeated failures within the specified period are to be counted as a single starting failure. Test starts and failures to start due to equipment not furnished under the contract shall not be counted as starting attempts, failures or successes.

NOTE 2 As a general assurance of readiness, if a unit has not experienced a successful start during the prior 30 days, then the starting attempt is considered as a "test start" and is not counted.

NOTE 3 Procedural errors that do not constitute equipment failure involving repair are not counted as failures-to-start.

NOTE 4 For calculation, FS = number of failures to start.

3.35
forced derating
unplanned component failure (immediate, delayed, postponed) or another condition that requires the load on the unit be reduced immediately or before the next weekend

3.36
forced derated hours
FDH
sum of all hours experienced during forced deratings

3.37
forced outage
FO
unplanned component failure (immediate, delayed, postponed) or another condition that requires the unit to be removed from service immediately or before the next planned shut down

3.38
forced outage factor
FOF
percentage of forced outage hours (FOH) to the period hours (PH):

$$\mathrm{FOF} = \frac{\mathrm{FOH}}{\mathrm{PH}} \times 100\ \%$$

3.39
forced outage hours
FOH
time, in hours, during which the unit or a major item of equipment was unavailable due to forced (unplanned) outages

3.40
forced outage rate
FOR

$$\mathrm{FOR} = \frac{\mathrm{FOH}}{\mathrm{FOH} + \mathrm{SH}} \times 100\ \%$$

3.41
combustion inspection
activity of determining the condition of the combustor section of the gas turbine (including the transition duct)

3.42
gross actual generation
GAG
actual amount of energy supplied

3.43
gross available capacity
GAC
greatest capacity at which a unit can operate with a reduction imposed by a derating

3.44
gross capacity factor
GCF

$$\mathrm{GCF} = \frac{\mathrm{GAG}}{(\mathrm{PH} \times \mathrm{GMC})} \times 100\ \%$$

3.45
gross dependable capacity
GDC
gross maximum capacity modified for seasonal limitations over a specified period of time

3.46
gross maximum capacity
GMC
maximum capacity a unit can sustain over a specified period of time when not restricted by seasonal or other deratings

3.47
gross output factor
GOF

$$\mathrm{GOF} = \frac{\mathrm{GAG}}{(\mathrm{SH} \times \mathrm{GMC})} \times 100\ \%$$

3.48
hot isostatic pressing
HIP
heat treatment process with simultaneous application of a high isostatic pressure

3.49
hot corrosion
accelerated oxidation of metals in the presence of salts, e.g. sodium sulfate, leading to degradation

NOTE The salts tend to dissolve the protective oxides on the metal, thus continuously consuming the base metal. Hot corrosion occurs mainly in the metal temperature range between 700 °C and 900 °C. In the presence of vanadium the hot corrosion will occur at even lower temperatures, down to 565 °C, by forming very corrosive and low melting phases of sodium vanadates.

3.50
hot section inspection
activity of determining the condition of the combustion system together with the turbine components of the gas turbine

3.51
hot testing
all functional tests commencing with firing leading to the gas turbine being regarded as operational

3.52
inhibition
avoiding vanadium hot corrosion by treating the fuel with additives, such as magnesium compounds, thus forming the magnesium vanadate phase with melting points higher than the metal temperature

NOTE Inhibition can lead to severe fouling of the turbine.

3.53
inspection
activity of determining the condition of a component or assembly and necessary replacement

3.54
invalid outage hours
IOH
includes all outage time not due to preserve, forced outage, planned outage and maintenance outage

EXAMPLES The following come under this category.

— force majeure events such as flood, storm, lightning strikes, externally caused fire, labour disputes, severe sandstorms, etc.;

— system problems, problems with the system to which the driven equipment is connected, excessive frequency and voltage swings and fuel pressure and flow.

3.55
load factor
mean value of the load during a time period under consideration, expressed as a percentage of the base load output of the gas turbine at actual site conditions