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Steam turbines - Part 1: Specifications

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Turbines à vapeur - Partie 1: Spécifications

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Partie 1:
Spécifications

Steam turbines

Part 1:
Specifications

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

STEAM TURBINES

Part 1: Specifications

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This part of International Standard IEC 45 has been prepared by IEC Technical Committee No. 5: Steam turbines.

The text of this part is based on the following documents:

Six Months' Rule	Report on Voting
5(CO)28	5(CO)31

Full information on the voting for the approval of this part can be found in the Voting Report indicated in the above table.

Annex A forms an integral part of this part of IEC 45.

INTRODUCTION

The first edition of IEC 45 was issued in 1931. Subsequent revisions were made, the last being in 1970. Since then, intensive development has resulted in the availability of more highly-rated turbines.

The development of turbines suitable for use with water-cooled nuclear reactors has proceeded in parallel, resulting in the production of large turbines for use with steam which is initially dry-saturated or slightly wet.

The demands made upon turbine control systems have increased simultaneously with the development of new control technologies, such as electro-hydraulic systems. Increased reliability, higher standards of dynamic performance, suitability for two-shift operation, and increased attention to health and safety are among the aspects now requiring high standards of achievement.

It has therefore become necessary to specify a turbine in more detail than was formerly needed. In consequence, this part of IEC 45 has been completely re-written, and is accordingly more comprehensive than earlier editions.

Wherever practicable, this part of IEC 45 takes into account the scope for applying to smaller turbines developments originally intended for larger machines, without implying that such applications would always be necessary or advantageous.

STEAM TURBINES

Part 1: Specifications

1 Scope and object

This part of International Standard IEC 45 is applicable primarily to steam turbines driving generators for electrical power services. Some of its provisions are relevant to turbines for other applications.

The purpose of this part is to make an intending purchaser aware of options and alternatives which he may wish to consider, and to enable him to state his technical requirements clearly to potential suppliers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part 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.

IEC 651: 1979, *Sound level meters.*

IEC 953-1: 1990, *Rules for steam turbine thermal acceptance tests - Part 1: Method A.*

IEC 953-2: 1990, *Rules for steam turbine thermal acceptance tests - Part 2: Method B.*

ISO 2372: 1974, *Mechanical vibration of machines with operating speeds from 10 to 200 rev/s. Basis for specifying evaluation standards.*

ISO 7919-1: 1986, *Mechanical vibration of non-reciprocating machines - Measurements on rotating shafts and evaluation - Part 1: General guidelines.*

3 Terms and definitions

For the purposes of this part, the following terms and definitions apply:

3.1 *Turbine type*

superheat turbine: A turbine whose initial steam is significantly superheated.

wet-steam turbine: A turbine whose initial steam is saturated or nearly so. (Also referred to as saturated-steam turbine.)

reheat turbine: A turbine from which the steam is extracted part-way through the expansion, reheated (one or more times) and readmitted to the turbine.

non-reheat turbine: A turbine in which the steam is not reheated.

mixed-pressure turbine: A turbine provided with separate inlets for steam supplied at two or more pressures.

back-pressure turbine: A turbine whose exhaust heat will be used to provide process heat, and whose exhaust is not directly connected to a condenser. The exhaust pressure will normally be above atmospheric pressure. (Also referred to as a non-condensing turbine.)

condensing turbine: A turbine whose exhaust is directly connected to a condenser. The exhaust pressure will normally be below atmospheric pressure.

regenerative-cycle turbine: A turbine from which some of the steam is extracted part-way through the expansion in order to heat feed water.

extraction turbine: A turbine in which some of the steam is extracted part-way through the expansion in order to provide process steam. If the turbine includes means for controlling the pressure of the extracted steam, it is called a controlled (or automatic) extraction turbine.

combined cycle: A combination of boiler, steam turbine and gas turbine, in which the gas turbine exhaust normally contributes to the heat input to the steam cycle.

single-line combined-cycle: A combined-cycle plant in which the steam turbine and gas turbine both drive the same generator. It is not possible to segregate the separate outputs of the steam turbine and the gas turbine; and definitions, such as those of heat rate or output given later in this standard, no longer apply.

NOTE - The terms in 3.1 may be combined to define the features of any particular unit.

3.2 *Methods of initial steam admission*

full-arc: All of the governing (control) valves supply steam uniformly to the admission inlet belt of the first stage.

partial-arc: The inlet belt to the first stage is divided into discrete arcs of admission, steam being supplied separately to each arc through, normally, one governing valve; governing valves operate wholly or partially in sequence.

3.3 *Conditions*

terminal conditions: The terminal conditions for a steam turbine or turbine-generator are the conditions imposed on the plant at their terminating points of the contract. These may typically comprise:

- initial and hot reheat steam conditions;
- cold reheat pressure;
- final feed water temperature;
- exhaust pressure;
- power output;
- speed;
- extraction requirements.

specified or rated terminal conditions: The conditions at the terminating points of the turbine or turbine-generator contract, with which specified output and/or heat rate shall be stated and/or guaranteed. Note that some nuclear steam generators supply steam at a pressure which increases as load reduces, and the turbine design must allow for this.

steam conditions: The conditions which define the thermodynamic state of steam, normally (static) pressure and temperature or dryness fraction (or quality). Steam pressure should always be quoted in absolute units, not as gauge pressure.

initial steam conditions: The steam conditions at inlet to the main stop valves.

maximum steam conditions: The highest steam conditions at which the turbine is required to operate continuously.

NOTE - The highest steam conditions should not exceed those permitted by 6.2 a) and 6.2 b).

induction steam conditions: The steam conditions of any additional steam entering the turbine at any pressure lower than the initial pressure.

dual steam conditions: The combination of initial and induction steam conditions appropriate to a mixed-pressure turbine.

reheat steam conditions: The steam conditions at the inlet to the reheat stop valves. (Also referred to as hot reheat steam conditions.)

cold reheat steam conditions: The steam conditions at the outlet of the turbine preceding the reheater.

extraction steam conditions: The steam conditions at the extraction connections of the turbine, of steam extracted for feed-heating or process purposes.

exhaust conditions: The steam conditions at the exhaust connection from the turbine.

NOTE - Use of the word "design" in respect of any steam conditions, power output, speed, etc., should be avoided in the contract documents. This terminology should only be applied to the values used in design calculations such as the design pressure for a pressure vessel.

3.4 *Speeds*

rated speed: The speed at which the turbine is specified to operate at its rated output.

maximum continuous speed: The upper limit of the operating speed of the turbine for continuous service.

overspeed trip setting: The speed at which the overspeed trip is set to operate.

temporary speed rise: The transient increase in turbine speed following a load rejection, with the speed governing system in operation. The rated temporary speed rise applies if the rated output is rejected at the rated speed.

maximum transient speed: Maximum rotational speed following rejection of maximum capability by disconnecting the generator from the electric system (with auxiliary supplies previously disconnected) and the speed governing (control) system in operation.

permanent speed rise: The final steady-state increase in turbine speed following a load rejection, with normal governor control.

maximum speed rise: The transient increase in turbine speed following a load rejection, with the speed governing system inoperative and the overspeed trip operative. The rated maximum speed rise applies if the rated output is rejected at rated speed.

3.5 *Powers*

NOTE - All these powers or outputs refer to operation of the turbine at rated terminal conditions (except where stated otherwise).

power: The power supplied by the turbine or its driven machine. The definition should state the position of measurement and any deductions for losses or auxiliary power. (Also referred to as output or load.)

net power at coupling: The power at the turbine coupling, less the power supplied to turbine auxiliaries if driven separately.

generator output: Power at the generator terminals, after the deduction of any external excitation power.

maximum continuous rating (MCR) (electrical generating set): The power output assigned to the turbine-generator by the supplier, at which the unit may be operated for an unlimited time, not exceeding the specified life, at the specified terminal conditions. This is the rating which will normally carry a guarantee of heat rate. The governing (control) valves will not necessarily be fully open. (Also referred to as rated output, rated power, or rated load.)

maximum continuous rating (MCR) (other than electrical generator drives): The power output assigned to the turbine by the supplier, at which the unit may be operated for an unlimited time, not exceeding the specified life, at the specified terminal conditions. This is the rating which will normally carry a guarantee of heat rate. The governing (control) valves will not necessarily be fully open. The power shall be that delivered at the turbine coupling, or the coupling of the driven machine, as may be agreed. (Also referred to as rated output, rated power, or rated load.)

maximum capability: The power output that the turbine can produce with the governing (control) valves fully open and at the specified terminal conditions. (Also referred to as valves-wide-open capability.)

maximum overload capability: The maximum power output that the unit can produce with the governing (control) valves fully open, and with the terminal conditions specified for over-load, e.g. with final feed water heater bypassed, or with increased initial steam pressure.

most economical continuous rating (ECR): The output at which the minimum heat rate or steam rate is achieved at the specified terminal conditions.

net electrical power: The generator output (with external excitation power deducted) minus the electrical auxiliary power.

electrical auxiliary power: Power taken by turbine and generator auxiliaries not driven by the turbine. This will normally include all power used for control, lubrication, generator cooling and sealing. It may also include additional auxiliaries such as motor-driven boiler feed pumps. The purchaser and contractor should agree on which additional auxiliaries should be included.

3.6 *Steam flow rate and steam rate*

initial steam flow rate: The flow rate of steam at initial conditions to the turbine, including any steam supplied to valve stems, glands, or balance pistons, and any steam supplied to auxiliary plant such as boiler feed pump turbines, steam/steam reheaters, ejectors, etc.

steam rate: The ratio of initial steam flow rate to power output.

3.7 *Heat rates*

(See also IEC 953, where the definitions are given in greater detail)

heat rate: The ratio of external heat input to the cycle to power output. It is the reciprocal of thermal efficiency.

guarantee heat rate: The heat rate upon which the guarantee or offer is based for a stated output with the rated terminal conditions, and for the cycle described in 19.1. Any assumption with regard to extraneous flows, make-up, heat addition or removal, shall be stated. In all cases, the formula used to define the heat rate shall be stated in the contract.

uncorrected test heat rate: The heat rate obtained by inserting test results in the formula stated in the contract.

fully-corrected heat rate: The heat rate which would have been achieved during the test if the terminal conditions had been as specified, and all ancillary plant outside the supplier's responsibility had performed exactly in accordance with its guarantee.

3.8 *Efficiency*

thermal efficiency: The reciprocal of heat rate, and therefore defined as the ratio of power output to external heat input to the cycle. If guaranteed, the definition of thermal efficiency shall be stated in the contract.

3.9 *Operational regimes (modes)*

base-load operation: Operation at maximum continuous rating (MCR) or a high fraction of this throughout a prolonged period.

two-shift operation: Operation at MCR or a high fraction of this for about 16 h or less out of 24 h per day, the remaining time being shut down.

one-shift operation: Operation at MCR or a high fraction of this for about 8 h out of 24 h per day, the remaining time being shut down.

load cycling: Operation alternating between high and low levels of load on a regular basis.

peak-load operation: Operation at high load for short periods, typically 1 h to 3 h, at times of peak demand. The number of peaks per day is not implied. The remaining time is spent shut down.

NOTE - Although the above definitions are of a general nature, they may be made more specific by stating whether the turbine is or is not subject to periodic shutdown, which might typically be categorized as a 36 h shutdown or a 48 h shutdown.

3.10 *Methods of load variation*

constant-pressure operation: Operation in which the initial steam pressure is maintained sensibly constant, and where load is reduced by gradually closing the governing (control) valves either in parallel (full-arc admission) or in sequence (partial-arc admission).

sliding-pressure operation: Operation in which load is changed by variation of the initial steam pressure; the governing (control) valves, which operate in parallel, all remaining at their fully-open position.

modified sliding-pressure: Operation in which load changes in the range from 100 % to about 90 % of rated output are achieved by operating all the governing (control) valves in parallel, the initial steam pressure remaining constant; below about 90 % of rated output changes of load are, where practicable, achieved by variations of the initial steam pressure, while the governing (control) valves remain near the position corresponding to 90 % of rated output.

hybrid operation: Operation of a partial-arc admission machine in which load is reduced by sequential closing of the governing (control) valves to a value corresponding to the minimum allowable number of governing (control) valves remaining fully open, the initial steam pressure remaining constant; further reduction of load is achieved by reduction in initial steam pressure while those governing (control) valves are open remain at or near their fully-open position.

throttle governing: The governing (control) valves operate in parallel, or nearly so, this being the normal control mode of a full-arc admission turbine in constant-pressure operation.

nozzle governing: The governing (control) valves close in sequence, this being the normal control mode of a partial-arc admission turbine in constant-pressure operation.

3.11 *Operational life*

calendar age: The total elapsed life of the plant, expressed in months or years, measured from first synchronization.

running hours: The number of hours during which the machine has been on load.

3.12 *Control and protection*

governing system: The combination of devices and mechanisms which convert control signals into valve positions in a characteristic manner. This includes the speed governor, the speed control mechanism, the speeder device (speed changer), the unloading systems and any steam valve operating devices.

turbine-generator protection system: The overall system provided to protect the turbine-generator from faults within itself or elsewhere in the electrical transmission system.

steady-state condition: A condition which has constant mean values of speed and load with limited random deviations.

stable operation: A system is said to be stable if it achieves a steady-state condition following a speed or load disturbance.

steady-state regulation (speed governing droop): Steady-state speed change expressed as a percentage of rated speed, when the load of an isolated unit is changed between rated load and zero load, with identical setting of the speed governing (control) system, assuming zero dead band.

steady-state incremental speed regulation (incremental speed droop): The rate of change of the steady-state speed with respect to load at a given steady-state speed and load, assuming zero dead band. The value is the slope of the tangent to the steady-state speed/load curve at the load under consideration.

dead band of the speed governing (control) system: The total magnitude of the change in steady-state speed (expressed as a percentage of rated speed) within which there is no resultant change in the position of the governing (control) valves. The dead band is a measure of the sensitivity of the system.

maximum load inaccuracy or non-linearity: The maximum deviation in load, expressed as a percentage of rated load, of the load-speed curve from the straight line corresponding to the overall speed droop, when operating under defined conditions of control equipment environment (e.g. temperature, humidity) and power supply (e.g. voltage, oil pressure).

governor environmental stability: The change in load, expressed as a percentage of rated load, resulting from a given change of any independent variable other than set point or speed. Such variables are lapsed time, temperature, vibration, barometric pressure, supply voltage and frequency.