
Methods of

Acceptance testing of industrial type steam turbines

Méthodes d'essais de réception pour les turbines industrielles de type à vapeur

Abnahmeprüfverfahren für Dampfturbinen in der Industrie

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Foreword

This British Standard, prepared under the direction of the Mechanical Engineering Standards Committee, provides the basis for acceptance tests for back pressure, mixed pressure, condensing and pass-out steam turbines as used in industrial and marine applications. It does not provide a basis for acceptance tests for turbines used for marine propulsion. It provides a basis for an accurate verification of the guarantees given by the manufacturers of such plant that is not covered by BS 752. Only such observations and measurements need be taken as are necessary for this purpose. Such tests are for the purpose of verifying guarantees regarding one or more of the following:

- output (or capacity);
- steam (or heat) consumption;

speed regulation;
emergency governor operation.

BS 752 deals with steam turbines for the very large outputs of modern machines in central stations, including reheat turbines. Where the requirements specified in BS 752 may be considered to be too demanding for reheat turbines at the lower outputs, this standard may be used with appropriate additions.

This British Standard is generally compatible with the 1962 edition of IEC Publication 46 'Recommendations for steam turbines — Part 2: Rules for acceptance tests' published by the International Electrotechnical Commission (IEC). It is intended to maintain this compatibility in any future revision.

British Standard Methods of

Acceptance testing of industrial type steam turbines

Section one. General

1. Scope

1.1 This British Standard provides for the carrying out of acceptance tests and for the computation and tabulation of the results for turbines of the following types:

- (a) complete expansion non-condensing turbines in which all the steam enters at one pressure and all the steam leaves at one pressure (straight back pressure turbines);
- (b) back pressure turbines similar to (a), except that steam is extracted at one or more controlled pressures for external processes (pass-out back pressure turbines);
- (c) complete expansion condensing turbines in which all the steam enters at one pressure and all the steam leaves at one pressure (straight condensing turbines);
- (d) condensing turbines similar to (c) but operating on a regenerative cycle, i.e. steam being extracted for heating the condensate (bled condensing turbines);
- (e) Condensing turbines from which steam is extracted at one or more controlled pressures for external processes (pass-out condensing turbines);
- (f) condensing turbines in which the steam is admitted at more than one pressure and all leaves at one pressure (mixed pressure condensing turbines);
- (g) condensing turbines similar to (f), except that steam is extracted at one or more controlled pressures (mixed pressure pass-out condensing turbines).

1.2 As in the case of turbines type (c) and (d), those of types (e), (f) and (g) may be arranged to operate on a regenerative cycle.

1.3 This British Standard, with appropriate additions, may also be applied to turbines similar to type (c) and (d), except that the steam is reheated after partial expansion (reheat turbines), where the size of the plant does not justify the application of the acceptance tests for large output steam turbines such as are covered by BS 752.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Notation and units

3.1 The quantities that enter into the tests and computations and the symbols used to denote them are shown in table 1.

Table 1. Quantities, symbols and units

Quantity	Symbol*	Units
Power	P	kW, MW
Mass rate of flow	M	kg/s, t/h
Absolute pressure	P	kPa, bar
Gauge pressure	p	kPa, bar
Temperature	t	°C
Specific enthalpy of steam	H	kJ/kg
Specific enthalpy of water	h	kJ/kg
Rotational speed	n	r/s, r/min
Heat	Q	kJ
Heat rate	q	kJ/(kW s), kJ/(kW h)
Thermal efficiency	η	%
Specific heat of water	c	kJ/(kg °C)
Density (mass/volume)	ρ	kg/m ³
Specific volume (volume/mass)	v	m ³ /kg

*These symbols have been chosen to agree as far as possible with BS 1991 : Part 1.

3.2 Conversion factors to other units may be taken from BS 350 : Part 1.

Section two. General principles for tests

4. Items on which agreement is mandatory

4.1 The date agreed for the guarantee performance tests shall be the earliest practicable. If this is delayed for any reason, it has to be recognized that there may be deleterious effects of corrosion and fouling upon the efficiency of the turbine (see 5.6). It is recommended that suitable records should be kept to determine any change in performance of the turbine up to the date of the test.

4.2 If preliminary tests or internal inspection prior to the acceptance test show evidence of deterioration, the parties to the test shall agree as to the action to be taken.

4.3 Throughout this British Standard, alternative methods are presented for the various details of the test and for deducing the results. Agreement shall be reached on the appropriate method to be used.

4.4 For any of the measurements necessary for an acceptance test methods other than those prescribed in the standard may be employed, provided that these methods

and any effect on the tolerances are agreed to by the parties to the test. Any departure from the prescribed methods shall be described in the test report.

4.5 All parties to the test shall agree on these matters before the test begins and shall designate the person who will direct the test and the person responsible for the operation of the machine.

4.6 Agreement shall be reached concerning the general method of operating the turbine during the test, on such matters as the means of securing a constancy of steam conditions and load, and on the disposition of manually-operated valves in connection with the turbine when their purpose is not clear with reference to performance guarantees.

4.7 Agreement shall be reached on the types and classes of instruments to be used.

5. Tolerance on test steam or heat rate

5.1 The test steam or heat rate is derived from the observations made, duly corrected in accordance with clauses **12**, **40** and **41**.

5.2 In considering the test results in relation to the guaranteed steam or heat rate, account shall be taken of the possible error in the test result due to the limits of accuracy of the instruments employed. It is not possible to guarantee the absolute accuracy of any reading however carefully the instruments employed have been calibrated. The purchaser and the manufacturer shall agree on the percentage error to be assigned to the measurement of each quantity appearing in the formula for the test steam or heat rate, and that the probable percentage error in the test result be taken as the square root of the sum of the squares of the percentage of errors in the test result corresponding to the agreed percentage errors of measurement in each of the quantities involved.

5.3 Where uncalibrated instruments are used, the limits of error in measurement in relation to the various quantities can be obtained, for example, from the following British Standards:

- (a) flow of water or steam : BS 1042
- (b) pressure : BS 1780
- (c) temperature : BS 1041
- (d) electrical power : BS 89

5.4 Where the turbine is driving a blower, compressor or pump, or any similar machine, and the power transmitted at the turbine coupling cannot be measured accurately, the overall performance is usually assessed from measurements determining the output of the driven machine. In these circumstances, special tolerances are required in accordance with the characteristics of the driven machine. The magnitude of such tolerances shall be agreed between the main contractor and the purchaser.

5.5 Apart from the errors in test measurements, further tolerances may be appropriate for certain classes of turbines, e.g. those working with a small heat drop or with relatively large pass-out steam flows, or those for which the specified duty has not correctly anticipated the operating conditions. Consequently, nothing in this standard shall preclude the purchaser and manufacturer from agreeing an overall tolerance to cover both errors of measurement and uncertainties in the conditions of operation.

5.6 If the guarantee performance test is delayed after the turbine is available for testing, or is delayed beyond the

date stated in the contract, it is recommended that an increase be allowed on the guarantee steam or heat rate up to the time of test, based on the total elapsed time.

The following allowances are given for guidance:

0 to 3 months	0
3 to 12 months	0.1 % per month
12 to 24 months	0.06 % per month

5.7 If necessary, a further allowance for the effects of incorrect operation, such as corrosion, shall be agreed between the parties to the test.

6. Preparation for the tests

6.1 Before the tests the plant shall be placed at the disposal of the manufacturer for examination in order to ascertain that it is in a suitable condition for the conduct of an acceptance test.

6.2 For speed responsive tests, it is normal practice to ensure the satisfactory performance of the whole governing and overspeed control systems by systematic testing and steps shall be taken to demonstrate that the systems are in a satisfactory working condition immediately before any tests involving partial or complete instantaneous unloading of the turbine.

6.3 For consumption tests, all unused connections shall be closed.

6.4 When the guarantees are based upon cooling water temperature and quantity, the condenser shall be clean and to the satisfaction of the condenser manufacturer.

6.5 Arrangements shall be made to measure any leakage of water or steam, inwards or outwards, that would affect the results of the tests.

7. Preliminary tests

7.1 Preliminary tests may be run for the purposes of:

- (a) determining whether the turbine and equipment are in a suitable condition for the conduct of an acceptance test;
- (b) checking of all instruments;
- (c) acquainting the testing personnel with test procedure.

7.2 If a preliminary test is made, by agreement between the purchaser and the manufacturer, it may be considered to be an acceptance test, if it has complied with all requirements for an acceptance test.

7.3 Preparatory to the test, the plant shall be run for a sufficient time to prove the attainment of steady working conditions. The duration of the trial shall be such as to permit several check readings to be obtained.

8. Duration

8.1 Each test shall continue for sufficient time to ensure accurate and consistent results as required for the measurements specified in section three.

8.2 For a test to determine capacity, the duration of the test shall be not less than 15 min and shall comprise not less than five consecutive sets of simultaneous readings of output and of the operating conditions, such as pressures and temperatures, that are required for steam or heat rate tests.

9. Constancy of test conditions

9.1 Any condition, the variation of which may affect the results of the test, shall be made as constant as practicable

before the test begins, and shall be so maintained throughout the test. Permissible deviations are given in table 2. If serious inconsistencies arise, either during a test or during the computation of results from a series of tests, the test or tests may be rejected in whole or in part and may be repeated if this is necessary to achieve the objects of the test.

9.2 Appropriate means may be employed, such as limiting the governor or valve gear travel, for securing constant load (within the prescribed load limits) during a steam (heat) consumption test provided that such means are consistent with the safe operation of the plant.

10. Measuring instruments

10.1 All the measuring instruments used shall be reliable and of suitable accuracy, and of a type appropriate to the quantity to be measured. They shall be so placed that sufficiently accurate observations may be obtained.

10.2 The agreed calibrations of all selected and agreed instruments shall be available to all interested parties before the tests start. If necessary, by agreement, instruments shall also be calibrated immediately after the tests.

11. Starting and stopping

Tests shall start (or stop) with the simultaneous initiation (or discontinuance) of the power or output observations and the water measuring or steam measuring. It is essential

that these observations be made simultaneously.

Other observations may begin somewhat before and stop somewhat after these times. All observations should preferably be made at times indicated by a visible or audible signal transmitted by an observer using an instrument as specified in 18.18.

12. Operating conditions

12.1 Every effort shall be made to run the test under the specified conditions of output, pressure and temperature, or as close to the specified conditions as practicable. The constancy of conditions as specified in 9.1 shall be maintained throughout the test. Except by agreement between the purchaser and the supplier, the maximum permissible deviation of the average test condition for each variable characteristic from that specified shall not exceed the limits prescribed in table 2.

12.2 The manufacturer's allowable variations in pressure, temperature and speed shall not be exceeded, unless specifically agreed to before the test.

12.3 For turbines specified and designed to operate on dry, saturated or slightly wet inlet steam, it is recommended that tests be carried out using slightly superheated steam (up to about 15 °C of superheat). This would avoid the difficulties in measuring accurately the moisture content of steam where the temperature is not above the saturation temperature at the prevailing pressure in order to ascertain

Table 2. Maximum permissible deviations of average test conditions

Variable characteristic	Permissible deviation of the average from that specified	Permissible fluctuation from the average value
(a) Initial steam pressure*	± 5 % of absolute pressure	± 2 % of absolute pressure
(b) Initial and reheat* steam temperature	Superheat < 25 °C: ± 8 °C Superheat ≥ 25 °C: ± 15 °C	± 6 °C
(c) Exhaust pressure*	Condensing turbine: +25 % of absolute pressure -10 % of absolute pressure Non-condensing turbine: ± 5 % of absolute pressure	± 5 % of absolute pressure
(d) Rotational speed	± 2 %	± 1 %
(e) Power factor	From unity to 0.05 below the rated power factor Example: Rated power factor is 0.90 The power factor shall be between 1.0 and 0.85	± 0.05
(f) Voltage	± 5 %	± 2 %
(g) Load	± 5 %	± 5 %
(h) Pass-out pressure*	± 5 % of absolute pressure	± 5 % of absolute pressure
(i) Pass-out flow	± 5 %	± 5 %
(j) Temperature of feedwater leaving final feedwater heater*	± 10 °C*	
(k) Condenser cooling water temperature*	± 5 °C	± 1 °C
(l) Condenser cooling water flow	± 15 %	± 1 %

* It is recommended that all these items taken together as appropriate should not lead to a deviation of enthalpy drop more than 7 %.