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Gas turbines — Acceptance tests

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2314 was drawn up by Technical Committee ISO/TC 70, *Internal combustion engines*.

It was approved in September 1971 by the Member Bodies of the following countries :

Belgium	Ireland	South Africa, Rep. of
Czechoslovakia	Italy	Sweden
Denmark	Japan	Switzerland
Egypt, Arab Rep. of	Netherlands	Thailand
France	New Zealand	United Kingdom
Germany	Portugal	U.S.A.
India	Romania	U.S.S.R.

No Member Body expressed disapproval of the document.

This International Standard is based on the *Recommendations for gas turbine acceptance tests* of the International Congress on Combustion Engines.

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Gas turbines — Acceptance tests

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard specifies standard procedures and rules for the conduct and reporting of acceptance tests in order to determine and/or verify the power, thermal efficiency and other performance characteristics of gas turbine power plants. It defines standard conditions which should be used if no other conditions are agreed at the time of purchase¹⁾. It also provides methods for correcting results obtained under test conditions to standard or other specified conditions. This International Standard is not intended to provide a basis for the conduct of test work generally aimed at development or research.

1.2 The acceptance requirements will have been satisfied if the compulsory tests outlined in 1.4 have been fulfilled under the procedures laid down.

Optional tests may, however, be included but should not be considered necessary unless specifically agreed upon by the parties to the test at the time of the purchase.

1.3 This International Standard is applicable to open cycle gas turbine power plants using normal combustion systems and also includes closed cycle and semi-closed cycle gas turbine power plants. In cases of gas turbines using free piston gas generators or special heat sources (for example, chemical process, nuclear reactors, furnace for a supercharged boiler), this International Standard may be used as a basis but will need to be suitably modified.

1.4 Compulsory tests

The primary object of the acceptance tests is to determine

- a) power under specified operating conditions (gas power, if only gas generator is supplied);
- b) thermal efficiency, heat rate or specific fuel consumption under specified operating conditions;
- c) adequacy of essential protective devices as defined in 7.1.3.

1.5 Optional tests

Optional tests may also be included, provided that these are specifically agreed upon by both parties at the time of purchase. For example, such tests may include any of the following items or others specified by national or local requirement :

- a) performance of the governing system and protective systems as given in 7.2.1 and 7.2.2;
- b) handling characteristics (for example, starting characteristics, time of loading);
- c) amplitude and frequency of vibration;
- d) stack emission;
- e) waste heat recovery evaluation;
- f) noise level;
- g) thermal discharges.

2 REFERENCES

ISO/R 495, *General requirements for the preparation of test codes for measuring the noise emitted by machines.*

ISO/R 541, *Measurement of fluid flow by means of orifice plates and nozzles.*

IEC Publication 34-2, *Rotating electrical machines. Part 2. Determination of efficiency of rotating electrical machinery.*

IEC Publication 46, *Recommendations for steam turbines. Part 2. Rules for acceptance tests.*

3 GENERAL DEFINITIONS, DESCRIPTIONS OF TERMS AND SYMBOLS

3.1 gas turbine : A machine which converts thermal energy into mechanical work; it consists of one or several rotating compressors, thermal device(s) to heat the working fluid, one or several turbines, a control system and essential auxiliary equipment. Any heat exchangers (waste heat exchanger excluded) in the main working fluid circuit are considered to be part of the gas turbine.

1) Points on which an agreement between parties to the test is to be reached at the time of the purchase or prior to the test are indicated by a vertical line to the left of the relevant text.

3.2 gas generator : Term commonly used to describe a combination of compressor(s) driven by a turbine (or turbines) with its combustion chamber, the whole providing hot gas under pressure. This combination may drive a separate power turbine, commonly having no compressor or combustion chamber.

3.3 Standard reference conditions

In cases where power, efficiency, heat rate or specific consumption refer to standard conditions, such conditions shall be :

- a) for the intake air at the compressor flange (alternatively, the compressor intake flare) as detailed in 6.6.2 – see also Figure 1 :
 - a total pressure of 1,013 bar (760 mmHg);
 - a total temperature of 15 °C;
 - a relative humidity of 60 %;
- b) for the exhaust at turbine exhaust flange (or recuperator outlet, if recuperator cycle is used) :
 - a static pressure of 1,013 bar (760 mmHg).

An inlet water temperature of 15 °C shall apply if cooling of the working fluid is used. Except in the case where intercooling is involved, or where water spray coolers are used, the effect of humidity may generally be ignored.

In the case of the closed cycle, the standard conditions for the air heater shall be 15 °C and 1,013 bar for the ambient atmospheric air.

3.4 Power

Power may be expressed in terms of output at the turbine coupling, electrical power (see 8.1) at the generator terminals or gas power in the case of a gas turbine or gas generator producing gas or compressed air (bleed air from a circuit compressor).

3.5 Thermal efficiency and specific consumption of heat

Thermal efficiency or specific consumption of heat shall be based on the lower calorific value, at constant pressure, of the fuel for either liquid, gaseous or solid fuel.

The calorific value used shall be based on a pressure of 1,013 bar and a temperature of 15 °C. Sensible heat above 15 °C shall be taken into account.

3.6 Cycle nomenclature

Figure 1 shows the basic nomenclature used in this International Standard. The station numbers refer to locations.

Ambient air conditions are read at Station 1. Air conditions at the inlet of the compressor and leaving the compressor section are read at Stations 2 and 3, respectively. In the event that there is more than one compressor section, the location for reading air conditions at the exit of the first compressor section is designated as Station 2.1 and the inlet of the second compressor section as Station 2.2. Station 4 is the entrance to the heat source (after recuperation if any). Station 5 is the exit from the heat source, and the inlet to the turbine is Station 6. If there should be more than one turbine, the exit conditions from the first turbine would be read at 6.1 and the entrance conditions to the second turbine at 6.2, etc. However, if a reheater were used in the cycle, then it would be 6.1 for the exit from the first turbine stage, 6.2 into the reheater, 6.3 out of the reheater, and 6.4 at the entrance of the second turbine. Exhaust gas conditions leaving the turbine are taken at 7 and leaving the stack at 8. In the event that heat recovery equipment is employed in the cycle, the entrance conditions to this equipment would be read at 7.1 and the exit conditions at 7.2, etc.

In addition to this nomenclature, the following letters designate the type of fluid in various parts of the cycle :

- f = fuel;
- g = gas after the heat source;
- a = air (or other working fluid);
- w = water;
- b = lubricating fluid.

Example : The temperature of the fuel at the entrance to the heat source would be designated as T_{f4} .

It is recognized that many different systems of station location designators are in use in lieu of that shown in Figure 1.

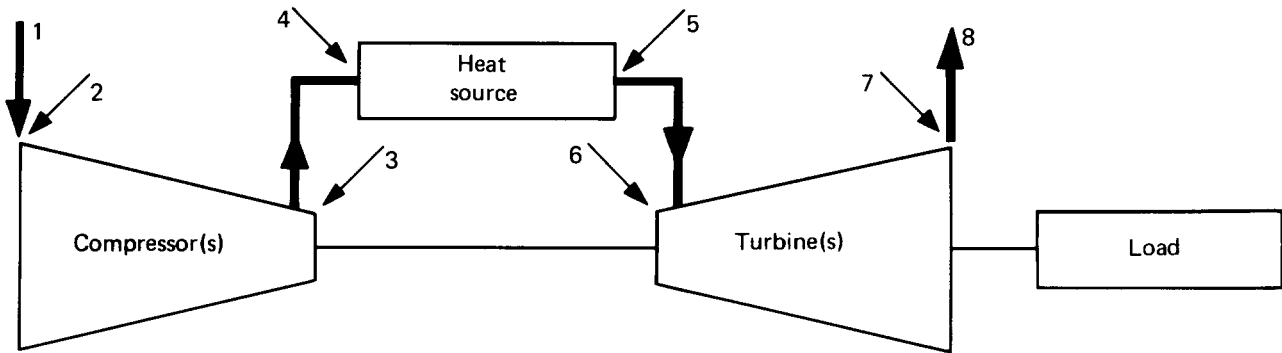


FIGURE 1 – Basic cycle nomenclature

3.7 Symbols

TABLE 1 — Symbols

Symbol	Definition	Unit	Clause
c_{pc}	specific heat of coolant	$\text{kJ}/(\text{kg}\cdot\text{K})$	8.5.7
h_{a0}	specific enthalpy of air at the standard reference temperature	kJ/kg	8.5.1 8.6.1
h_{a1}	specific enthalpy of air at temperature T_{a1} entering the control volume	kJ/kg	8.5.1
h_{a3}	specific enthalpy of air at temperature T_{a3} leaving the compressor	kJ/kg	8.6.3
h_{a4}	specific enthalpy of air at temperature T_{a4} entering the heat source (combustion chamber) and after any heat exchanger	kJ/kg	8.6.1
h_{ae}	specific enthalpy of air at temperature T_e leaking from the control volume	kJ/kg	8.5.1
h_{f4}	specific enthalpy of fuel at temperature T_{f4} entering the heat source (combustion chamber)	kJ/kg	8.2.1 8.5.1
h_{g0}	specific enthalpy of combustion products at the standard reference temperature	kJ/kg	8.5.1
h_{g6}	mean specific enthalpy of gases at temperature T_{g6} entering the turbine	kJ/kg	8.6.1
$h_{g6.1}$	specific enthalpy of gas at temperature $T_{g6.1}$ leaving the turbine driving the compressor	kJ/kg	8.6.3
$h_{g6.2}$	specific enthalpy of gas at temperature $T_{g6.2}$ entering the power turbine	kJ/kg	8.5.12
h_{g7}	specific enthalpy of gas at temperature T_{g7} leaving the power turbine	kJ/kg	8.5.12
h_{g8}	specific enthalpy of exhaust gases at temperature T_{g8}	kJ/kg	8.5.1
$h_{g \text{ in}}$	specific enthalpy of gas at temperature $T_{g \text{ in}}$ and pressure $p_{g \text{ in}}$ entering the driven device	kJ/kg	8.5.11
$h_{g \text{ out}}$	specific enthalpy of gas at temperature $T_{g \text{ out}}$ and pressure $p_{g \text{ out}}$ leaving the driven device	kJ/kg	8.5.11
h_0	specific enthalpy of the fuel at 15°C	kJ/kg	{ 8.5.1 8.2.1 8.3.3 e)
m	rate of fuel consumption	kg/s	8.2.1
m_{a1}	mass rate of air entering the control volume	kg/s	8.5.1
m_{a4}	mass rate of air entering the combustion chamber	kg/s	8.6.1
m_c	mass rate of coolant flowing through the lubricant cooling system	kg/s	{ 8.5.1 8.5.7
m_e	mass rate of sealing and/or extracted air leaving the control volume	kg/s	{ 8.5.1 8.5.2 8.6.3
m_{f4}	mass rate of fuel entering the control volume	kg/s	{ 8.5.1 8.6.1
m_{g5}	mass rate of gas leaving the combustion chamber	kg/s	{ 8.6.1 8.6.3
m_{g7}	mass rate of gas leaving the turbine	kg/s	8.5.12
m_{g8}	mass rate of exhaust gases leaving the control volume	kg/s	8.5.1
m_{in}	mass rate of gas entering the load device	kg/s	8.5.11
m_m	measured rate of fuel consumption	kg/s	8.3.3 e)

TABLE 1 – Symbols (continued)

Symbol	Definition	Unit	Clause
m_τ	mass of fuel used during period τ	kg	8.2.1
M	torque	kN·m	8.1.1
n	speed	rev/min	8.1.1
n_0	reference speed	rev/min	8.3.3 a)
n_t	test speed	rev/min	8.3.3 a)
P	net shaft power output	kW	8.2.2 8.2.3
P_c	net corrected shaft power output	kW	8.3.3 c)
P_{gr}	gross shaft power output	kW	8.1.1
P_m	measured shaft power output	kW	8.6.2
P_s	shaft power output	kW	8.5.1 8.5.11 8.5.12
P_t	test net shaft power output	kW	8.3.3 c) 8.3.3 e)
q	heat consumption	kW	8.2.2 8.2.3
q_p	heat rate	kW heat/kW power	8.2.3
q_r	rate of heat consumption	kW	8.2.1
Q_{l0}	lower calorific value of the fuel at 15 °C and constant pressure	kJ/kg	8.3.3 e) 8.5.1 8.2.1
Q_m	mechanical losses	kW	8.5.1
Q_{mc}	mechanical losses of the driven compressor, excluding the losses of speed changing, if used	kW	8.5.11 8.6.3
Q_{mt}	mechanical losses of the power turbine, inclusive of speed changing gears, if used	kW	8.5.12 8.6.3
Q_r	radiation and convection heat losses from the control volume	kW	8.5.1
Q_{rc}	radiation heat losses from the driven compressor casing	kW	8.5.11
Q_{rt}	radiation and convection heat losses from the power turbine casing between temperature measuring stations $T_{6.2}$ and T_7	kW	8.5.12
T_{a1}	flow weighted average temperature of air entering the control volume	K	8.5.1
T_{a4}	air temperature at the entrance of the heat source (combustion chamber)	K	8.6.1
T_{in}	inlet temperature of the lubricant coolant	K	8.5.1
T_{out}	outlet temperature of the lubricant coolant	K	8.5.1
$T_{out} - T_{in}$	temperature rise of coolant through the oil cooler	K	8.5.7
T_{f4}	fuel temperature	K	8.6.1
T_{g6}	gas temperature at entrance to turbine	K	8.6.1
T_{g8}	flow weighted average temperature of gas leaving the control volume	K	8.5.1
T	absolute reference temperature	K	8.3.3 a)
T_t	absolute test temperature	K	8.3.3 b)

TABLE 1 — Symbols (concluded)

Symbol	Definition	Unit	Clause
δ	the ratio of absolute ambient test pressure to the absolute ambient reference pressure	—	8.3.3 c)
η_t	thermal efficiency	—	{ 8.2.2 8.3.3 e)
η_{tc}	combustion chamber efficiency	—	{ 8.5.1 8.6.1
θ	the ratio of absolute ambient test temperature to the absolute ambient reference temperature	—	8.3.3 a)
τ	duration of test	s	8.2.1
ω	angular velocity	rad/s	8.1.1

4 PREPARATION FOR TESTS

4.1 The acceptance tests shall normally be carried out immediately after the completion of the setting up period by the manufacturer and, in any event, within a period of three months, unless otherwise agreed by both parties. In any case, before the tests, the machine shall be placed at the disposal of the manufacturer for examination and cleaning.

4.2 If pipes or ducts are fitted for the purpose of by-passing any component, or if bleed-off is used for any service, any valves in such ducts or pipes shall be set so as to produce conditions specified in the guarantee.

4.3 Dimensions and physical conditions of parts of the gas turbine required for calculations or other special purposes of the tests shall be determined and recorded prior to the tests. Serial numbers and data on name-plates shall be recorded to identify the gas turbine engine auxiliary equipment tested.

4.4 Preliminary tests may be run for the purpose of

- a) determining whether the gas turbine and associated plant are in a suitable condition for the conduct of an acceptance test;
- b) checking instrumentation;
- c) familiarization with test procedure.

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

5 OPERATING CONDITIONS FOR THE TEST

5.1 General

5.1.1 Every reasonable effort shall be made to run the test as close as possible to the reference operating conditions (standard conditions or other specified conditions agreed at the time of purchase). Fuel employed for test shall, wherever possible, be such as specified in the guarantee or substantially similar to it in properties. In case this is not possible, prior agreement shall be reached between the parties to the test as to the fuel to be used at an acceptance test and as to the interpretation of the results.

5.1.2 For convenience, thermal efficiency tests in dual fuel installations may be carried out with one fuel only, but only after agreement between the parties to the test.

5.1.3 Special adjustments inappropriate for normal engine operation require written agreement.

5.1.4 The test observation records shall be entered on carefully prepared forms which constitute original logsheets to be authenticated by the observer's signature. The original sheets and recorded charts shall be such as to permit facsimile reproduction as, for example, by carbon copies or by photocopying process.

Hand copying is not permissible. For the acceptance tests, a complete set of unaltered logsheets and recorded charts will become the property of the parties to the test. The observations shall include the date and time of day. They shall be the actual readings without application of any instrument corrections. The logsheets and any recorded charts shall constitute a complete record.

5.1.5 If, during the conduct of a test or during the subsequent analysis or interpretation of the observed data, an obvious inconsistency is found which affects the validity of the results, every reasonable attempt shall be made to adjust or eliminate the inconsistency by mutual agreement. Failure to reach agreement will invalidate the run or test.

5.2 Operating conditions

5.2.1 Certain tests, as for example those of 1.4 a), b) and 1.5 c), e), f), will normally be carried out at steady state conditions.

5.2.2 Preparatory to any test, the gas turbine power plant shall be run until steady state conditions have been established. Steady state is achieved when the key parameters associated with the test objectives have been stabilized.

Stability will be achieved when continuous monitoring indicates that readings have been within the maximum permissible variation in accordance with the succeeding clause and Table 2 for a period of time which is agreed upon by the parties to the test.

5.2.3 In determining the rated performance under any condition, evaluation of power and efficiency shall be carried out three times consecutively, the duration of each test being not less than 5 min and not longer than 20 min (i.e. a total period of not less than 15 min and not longer than 60 min). If the fuel flow is measured by weighing, the test period could be longer than 20 min in order to achieve adequate accuracy.

During any evaluation, the load shall be held steady within $\pm 1\%$ while readings are taken. If this is not possible, at least five sets of readings spread over the period as stated above shall be taken for each evaluation and the results averaged. Where the maximum fluctuation in load exceeds $\pm 2\%$, the test shall be accepted only by mutual agreement.

Each observation of an operating condition during the overall period of the test shall not vary from the reported average for that operating condition by more than the amount shown in Table 2, except by written agreement between the parties to the test.

NOTE – If the variations to be measured are rapid and irregular, the use of suitable instruments is to be preferred to directly observed readings. In cases which require each set of observations to be used for calculating a result, and where results are then averaged, simultaneous readings or recordings are required. If observations are made to determine rates by sums or differences, the exact time of making the observation is necessary.

TABLE 2 – Maximum permissible variations in operating conditions

Variable	Variation of any observation from reported average operating condition during a test run
1. Speed of rotation of output shaft	$\pm 1\%$
2. Barometric pressure at test site	$\pm 1\%$
3. Temperature of working fluid at compressor inlet	$\pm 2^\circ\text{C}$
4. Calorific value of liquid fuel, per kilogram (high- and low-heat values)	$\pm 2\%$
5. Calorific value of gaseous fuel, per cubic metre (high- and low-heat values from continuous calorimeters) ¹⁾	$\pm 2\%$
6. Pressure of gaseous fuel, as supplied to the plant	$\pm 1\%$ of absolute equivalent of average pressure
7. Temperature of fuel, as supplied to the plant ¹⁾	$\pm 3^\circ\text{C}$
8. Exhaust back pressure	$\pm 1\%$ of absolute equivalent of average pressure
9. Working fluid inlet pressure	$\pm 1\%$ of absolute equivalent of average pressure
10. Coolant temperature : inlet ²⁾	$\pm 3^\circ\text{C}$
11. Coolant temperature : rise ¹⁾	$\pm 2^\circ\text{C}$

1) For gaseous fuels other than natural gas, the allowable variation shall be specified by prior agreement.

2) Applicable where precoolers, intercoolers or aftercoolers are used.

6 INSTRUMENTS AND METHODS OF MEASUREMENT

6.1 General

This section describes the instruments, methods and precautions to be employed in testing gas turbine power plants and components in accordance with this International Standard. Where there is no specification in this section concerning the instruments and the method of measurement used, these are subject to agreement by the parties to the test.

6.2 Check list of instruments and apparatus for compulsory tests

a) Instruments to measure the power output of the gas turbine.

b) Apparatus for measuring fuel consumption of the gas turbine or the heat energy supplied to it.

c) Apparatus for determining the calorific value of the fuel, its ash content and composition.

Alternatively samples should be taken for tests in a laboratory agreed upon by both parties.

d) Instruments for determining the relative density (specific gravity) of the fuel.

Alternatively samples should be taken for tests in a laboratory agreed upon by both parties.

e) Manometers or pressure gauges for determining pressures and pressure differences at appropriate points on the gas turbine system (for pressure measurements affecting performance evaluation, liquid manometers are preferred).

f) Barometer.

g) Instruments needed for the indirect determination of the turbine inlet gas temperature (except in the case of closed cycle turbines).

h) Instrument(s) for determining the temperature at the compressor inlet.

i) Thermometers for determining the temperature of the fuel in the measuring tanks and circulating water in the coolers.

j) Speed of rotation indicators and manual or electronic revolution counters.

k) Master clock with synchronized signalling system, or, if this is not possible, synchronized watches or clocks.

l) Instruments for determining atmospheric humidity.

6.3 Power measurement

6.3.1 Power measurement, mechanical

6.3.1.1 Torque measurement

Either of the following types of apparatus may be used to measure torques used in the derivation of the mechanical outputs of gas turbines.

1) Absorption dynamometers (mechanical, electrical or any fluid types, or a combination of any of these)

The dynamometer selected shall be chosen so that the minimum measured torque at any speed is at least 20 % of its normal maximum rated torque. Absorption dynamometers shall be so constructed that the cooling fluid enters and leaves in a plane through the axis so as to avoid tangential velocity components. Similar precautions shall also be taken regarding external windage. Hose connections, if used, shall impose no sensible tangential restraint. Dashpots, if used for damping oscillations, shall be demonstrated to impose equal resistance to motion in either direction. Effective radius arms of dynamometers shall be measured with an error not exceeding $\pm 0,1$ %. A manufacturer's certificate may be accepted as sufficient evidence.

The force measuring device shall be checked against certified weights in the directions of both increasing and decreasing load. The positive or negative error of the force measuring device shall not exceed 0,1 % of the maximum load to be read in the test. The average of increasing and decreasing loadings shall be accepted as the calibration only if the difference remains within 0,3 % of the maximum test load.

Before and after acceptance tests, dynamometers shall be carefully examined and any unbalance of the arms determined. Tests shall be considered unsatisfactory should there be irregularities in the operation of the dynamometer, for example a periodic surging of load, such as might be due to the action of water in the dynamometer, or some resonant condition that produces pulsations of indicated torque in excess of ± 2 %.

2) Shaft torque meter

The shaft torque meter shall be calibrated before the test series. If the system is affected by temperature, it shall be recalibrated after the test at the temperature experienced during the test. Calibration shall be performed with the torsion indicating means undisturbed from pre-test to the end of the post-test determination. In any case, observations shall be taken with a series of increasing loadings to a value above maximum test readings, followed by a series of decreasing loadings. Loadings shall always progress in one direction except at maximum value. The average of increasing and decreasing loadings shall be accepted as the calibration only if the difference is within 1,0 % of the maximum test load.

Dynamometer readings shall be taken with sufficient frequency that the average of all readings will not differ from the average of alternate readings (average value of even and uneven readings) by more than 0,2 %.

6.3.1.2 Speed measurement

An instrument of the speed indicating type may be used for initial setting of the test speed and for checking constancy of speed during test periods. Each shaft of a multi-shaft engine shall be equipped with a speed indicating device.

For checking constancy of speed during test periods, suppressed range recording tachometers are recommended for visual read-out as well as recording. Periodic cross checking with extremely accurate electronic pulse counter type speed indicators can improve attainable accuracies of such recorders.

Either positively driven or no-contact type tachometers shall be used for all speeds. Hand-held tachometers are not recommended, because of the possibility of slip.

When mean rotative speed influences test results, an integrating type revolution counter, positively driven from the shaft, shall be used. Counting and time accuracy shall be such that error in mean speed does not exceed $\pm 0,25$ %. Whenever electronic type pulse counters are used for power and efficiency determinations, readings shall be taken with sufficient frequency that the average of all readings will not differ from the average of alternate readings by more than 0,25 %.

6.3.2 Power measurement, electrical

These tests shall be performed in accordance with International Electrotechnical Commission (IEC) publication 46.

6.3.3 Power measurement, other cases

Where output is in a form which is not electrical and when it is not practicable to measure the output on the shaft itself (for example pumps, compressors, etc), reference shall be made to the appropriate standard for testing the driven machine. Such standards may be used only after mutual agreement by the parties involved.

6.3.4 Power output determined by thermodynamic computations

When it is not possible to measure shaft power by the previously stated means (6.3.1, 6.3.2 and 6.3.3) it may, under limited conditions, with a maximum error of ± 5 %, be computed from measured values of the working fluid mass flow, the air and gas temperatures, the heat consumption, the bearing friction loss, and the turbine heat loss to the environment. This method may be used in the event that similar measurements on the load device are not practical, such as

- a) insufficient knowledge of working fluid properties of the driven machine;
- b) temperature rise of load device too small to measure;
- c) load device involves several fluid streams, extractions, etc.

The thermodynamic calculation procedure to be used is described in 8.5.

6.3.5 Power measurement, gas generator

The power of a gas generator can be determined by replacing the power turbine by a nozzle or equivalent opening at full load. The power is defined as that produced by an isentropic expansion from measured conditions at generator outlet (total pressure and temperature) to the ambient atmospheric pressure.

6.4 Fuel measurement

6.4.1 Liquid fuel measurements

6.4.1.1 Liquid fuel characteristics

Parties to the test shall agree upon the fuel sampling method. Fuel characteristics shall include the determination of

- a) density (mass per unit volume);
- b) calorific value;
- c) viscosity where applicable;
- d) temperature if additional heating is required.

Density may be obtained by hydrometer or by direct weighing means.

Calorific value may be obtained by either of the following two methods.

- The higher calorific value at constant volume may be determined by means of a bomb calorimeter, and the lower calorific value at constant volume determined by deducting the latent heat of the calculated amount of water vapour produced from the measured hydrogen content of the fuel. Then the lower calorific value at constant pressure is found by calculation. The foregoing determination should be carried out by a physical or chemical laboratory agreed upon by both parties.
- When it is not possible to run a bomb calorimeter test and when agreed upon by both parties, the lower calorific value at constant pressure can be estimated from measured density (hydrometer) with the curve shown in Figure 2. The accuracy is estimated to be within ± 1 % depending on fuel properties.

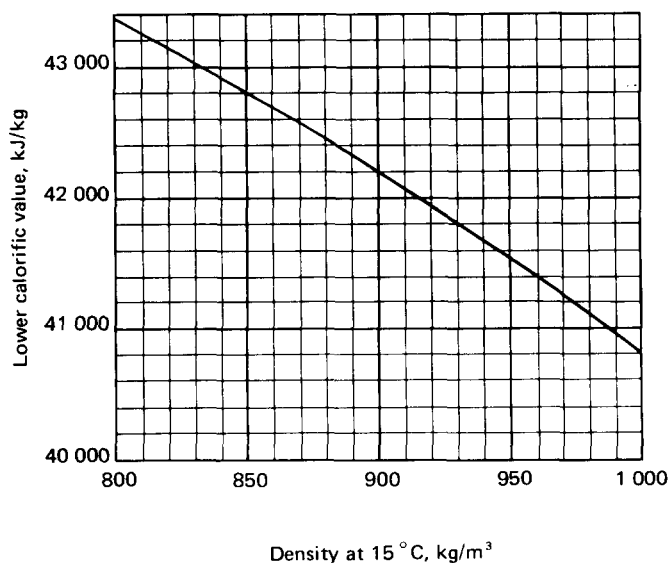


FIGURE 2 — Lower heat calorific value of liquid fuels as a function of density

In each case, adjustment shall be made for sensible heat of the fuel above 15 °C in accordance with 3.5. In the absence of specific measurements, the following heat content may be taken for the fuels :

— for gas oil viscosity

$< 9,5 \times 10^{-6} \text{ m}^2 \cdot \text{s}^{-1}$ at 20 °C : for every 1 °C above 15 °C add 1,88 kJ/kg;

— for light fuel oil viscosity

$< 49 \times 10^{-6} \text{ m}^2 \cdot \text{s}^{-1}$ at 20 °C : for every 1 °C above 15 °C add 1,76 kJ/kg;

— for medium fuel oil viscosity

$< 110 \times 10^{-6} \text{ m}^2 \cdot \text{s}^{-1}$ at 50 °C : for every 1 °C above 15 °C add 1,63 kJ/kg;

— for heavy or extra heavy fuel oil viscosity

$< 380 \times 10^{-6} \text{ m}^2 \cdot \text{s}^{-1}$ at 50 °C : for every 1 °C above 15 °C add 1,59 kJ/kg.

6.4.1.2 Flow measurements

The accurate measurement of fuel flow to the gas turbine is necessary to determine gas turbine power plant heat rate. The use of flow nozzles, orifices, venturi meters, liquid meters or direct weighing means are recommended. When nozzles, orifices or venturi meters are used, they shall be constructed, arranged and instrumented in accordance with a recognized standard, for example ISO/R 541. In any case, the fuel flow measuring device shall be suitably calibrated to ensure that the maximum error is less than $\pm 0,5 \%$.

Calibrated volumetric measuring tanks may also be used, provided it can be demonstrated that an accuracy of measurement of $\pm 0,5 \%$ is obtainable.

A weigh tank system shall be free upon its pivot and unconstrained by any external force such as might be applied by unsuitably designed or unsuitably placed pipe connections. It shall be calibrated before the test by adding known weights to the tank structure and plotting curves with load increasing and load decreasing. It is necessary to establish the reason for any difference between these two curves before the test proceeds. The overall maximum error of measurement shall not exceed $\pm 0,5 \%$ of the measured quantity.

Any spill or leakage from control valves or burners shall either be reintroduced into the fuel system on the engine side of the measuring means or its quantity shall be separately measured and deducted. If liquid meters such as positive displacement or turbo-types of demonstrated accuracy and reliability are used, the viscosity of the fuel at the meter shall lie within the range stipulated by the manufacturer of the meter.

6.4.2 Gaseous fuel measurements

6.4.2.1 Gaseous fuel characteristics

Gaseous fuel characteristics shall include the determination of

- density (mass per unit volume);
- calorific value;
- dust content where applicable;
- temperature.

Upon agreement between the parties to the test, *calorific value* and *density* may be calculated or taken from records of the gas supplier, provided the dates and times of the records are concurrent with test dates and times, and the bases of the values selected are completely described in the test reports.

For blast furnace or refinery gas and other gases, the composition of which varies continuously, sampling shall be carried out with such frequency during the period of the test that a fair and representative calorific value of the gas is obtained by averaging the results. When possible, it is recommended that a continuous recording calorimeter and a density meter be used during the test.

Calorific value

The lower calorific value of gaseous fuel may be determined by computation, using the individual calorific values at constant pressure of the component gases and their proportions in the fuel. Alternatively a Junkers calorimeter or any other type of demonstrable accuracy may be used.

The method to be used shall be previously agreed upon by both parties. In any case, adjustment shall be made for sensible heat of the fuel above 15 °C (in accordance with 3.5).

Dust content

In certain gaseous fuels such as blast furnace gas, dust will be of importance and has to be measured. Dust content may have an influence on measurements of gas mass flow. However, owing to the wide range of dust characteristics, loadings, etc, the parties shall agree previously on the procedure to be used by a qualified person experienced in this class of work.

6.4.2.2 Flow measurements

Gas fuel consumption may be determined by means of either a positive displacement volumetric meter or a turbine type flow meter. Fuel meters must be individually calibrated to reduce the maximum error in measurement of fuel consumption to $\pm 1,0\%$.

In the event of such a method not being practicable, gas consumption may be determined from flow measurement by means of nozzles, orifices or venturi meters, which shall be constructed, arranged and instrumented in accordance with a recognized standard, for example, ISO/R 541. If the gas has a high dust content, the dust can introduce errors in the flow measurement.

6.4.3 Solid fuel measurements (especially for closed cycle installations)

The appropriate national standards or International Standards shall be used.

6.5 Temperature measurements

Each temperature measuring device shall be calibrated or compared with an instrument certified by a recognized authority. Recommended instruments for measuring temperatures directly are :

- a) mercury-in-glass thermometers;
- b) thermocouples with potentiometer or similar instruments;
- c) resistance thermometers.

When the dynamic component of temperature exceeds $0,5^{\circ}\text{C}$, a stagnation (total temperature) type thermometer shall be used, or alternatively the appropriate correction shall be applied to the measurement made with a normal thermometer.

6.5.1 Compressor inlet temperature

The compressor inlet temperature shall be measured to an accuracy such that the maximum error will not exceed $1,0^{\circ}\text{C}$. The instrument used shall have a sensitivity of $0,2^{\circ}\text{C}$ and an accuracy of $0,5^{\circ}\text{C}$.

Generally two sensors shall be used and readings taken simultaneously to give a mean value.

If, for any reason, the parties decide to take the measurements at a location different from that stated in 3.3, agreement shall be reached regarding the corrections to be applied.

6.5.2 Turbine outlet temperature

The instrument used to measure the turbine outlet temperature shall have a sensitivity equal to or better than $1,0^{\circ}\text{C}$ and an accuracy equal to or better than 3°C . The casing and the duct between the turbine exhaust flange and the measuring station shall be well insulated.

The location of the measuring station shall be selected to minimize velocity and temperature gradients. Four sensors shall be located at centres of equal areas. For the closed cycle turbine two sensors can be sufficient.

The exhaust temperature shall be taken as the mean value of the four measurements. (If, for practical reasons, it is necessary to place the sensors close to, or at, the turbine exhaust flange, more than four sensors may be required to give adequate accuracy. In this event, the number and position of sensors shall be subject to special agreement by the parties concerned.)

Each temperature sensor shall be shielded to minimize radiation error, if exposed to radiation over a significant angle from parts at a temperature which differs from gas temperature by more than 15°C .

6.5.3 Turbine inlet temperature

Except for special cases, for example closed cycle, direct measurement of mean turbine inlet temperature is very difficult. It is generally necessary to determine the latter by indirect means, such as those given in 8.6. For the closed cycle installations two sensors can be used.

6.5.4 Combustion chamber air inlet temperature.

It may be necessary (see 8.6) to determine the mean total temperature at the inlet to the combustion chamber and estimate the temperature rise therein. Methods for measurement of the mean total temperature at the entry to the combustion chamber will vary according to the detailed design of the machine. Necessary precautions shall be taken into account against radiation (see 6.5.2).

6.5.5 Fuel temperature

Fuel temperature shall be measured at the entrance of the control volume (see 8.5.1 and Figure 3).

6.5.6 Where the compulsory test requires measurement of heat extracted by the lubricant coolers, intercoolers and vents, as in the case of indirect measurements of mechanical power, the accuracy temperature and flow measurements shall permit determination of heat extraction with a maximum error no greater than 10% .

Where such measurements are not required for the compulsory test, the measurement accuracy and the means of measurement shall be determined by mutual agreement of the parties concerned.

6.6 Pressure measurements

Manometers (U-tube or single leg), deadweight gauges, Bourdon or other elastic type gauges shall be used. Bourdon or other elastic type gauges shall be calibrated against deadweight gauges. For the U-tube or single leg type manometer, attention is drawn to possible dimensional changes of scale. Other elastic means such as calibrated pressure transducers may be used.

Connecting piping shall be demonstrated to be leak free under working conditions. If pressure is fluctuating, a suitable means of damping shall be used in the connecting tubes.

6.6.1 Barometric pressure

Barometric pressure shall be determined by any suitable means providing maximum error not exceeding 0,25 mmHg. A barometer shall be located in a stable environment at the test site. By agreement between both parties, the barometric pressure given by a recognized local authority may be used after altitude correction has been made.

6.6.2 Compressor inlet pressure

Compressor inlet pressure is defined as the total pressure prevailing at compressor inlet. It is an absolute pressure based on the algebraic sum of the barometric pressure, the gauge static pressure and the dynamic pressure, when the quantities are measured and evaluated separately. The dynamic pressure is usually calculated using the mean velocity in the section where static pressures are measured. This mean velocity is computed from the area of this section and the rated flow.

If no inlet duct, silencer or filter is used, inlet pressure shall be taken as barometric pressure.

Where the mean velocity at the compressor flange or in the vicinity of the compressor inlet flare (if applicable) is below 20 m/s, static pressure may be measured at one station only. In the event of the velocity being higher than 20 m/s, static pressure shall be taken as the arithmetic average of the readings at four stations, placed as near symmetrically as possible in a plane normal to the mean flow. Such measurements shall be taken by means of liquid manometers.

For closed cycle installations the procedure for measuring compressor inlet pressure shall be the same as that specified for compressor outlet pressure (see 6.6.4).

6.6.3 Turbine outlet pressure

Turbine outlet pressure is defined as the static pressure prevailing at turbine exhaust flange (or regenerator outlet flange, if a regenerative cycle is used), and is obtained in the same manner as for the compressor inlet pressure. The static pressure shall be taken as the arithmetic average of the measurements at four stations placed as nearly symmetrically as possible in the section.

If no outlet duct is used, outlet static pressure shall be taken as barometric pressure.

6.6.4 Compressor outlet pressure and turbine inlet pressure

If turbine inlet temperature is determined by indirect means, it may be necessary to measure the compressor outlet pressure or, if practicable, the turbine inlet pressure.

Static pressure shall be taken as the arithmetic average of the measurements at four stations placed as near symmetrically as possible in the exhaust section of the compressor or the inlet section of the turbine. Dynamic pressure shall be computed from the estimated mean velocity in the relevant section.

6.7 Flow measurements

6.7.1 Working fluid

Where the compulsory test requires the measurement of the rate of flow of the working fluid, as in the thermodynamic calculation of the power output, this shall be carried out with nozzles or orifices constructed, arranged and instrumented in accordance with a recognized standard (for example, ISO/R 541). When it is not possible to use standardized nozzles or orifices, pitot probes or other velocity probes, when agreed by both parties, can be used for flow measurement. In this case, detailed determinations of velocity profiles at the measuring station are required. The accuracy of the manometers used shall be within $\pm 0,5\%$ of the differential pressure reading.

If it is necessary to estimate the mass flow at a point in the cycle other than that at which measurements can be made, allowance shall be made, if relevant, for cooling air bleed, blow off, gland losses, fuel input, water drained from intercoolers, etc.

6.7.2 Fuel flow

See 6.4.1.2 and 6.4.2.2.

6.7.3 Secondary flows

If required, the measurement of coolant, oil and other secondary flows may be accomplished by one of the following methods :

- standard nozzle or orifice;
- positive displacement meter;
- weir-notch method;
- other agreed methods such as direct weighing, use of volumetric tanks, etc.

6.8 Measurements concerning governing system, noise, etc.

See section 7.

7 METHOD OF TESTING

7.1 Compulsory tests

7.1.1 Power determination (see 6.3)

The power absorbed by the separately driven auxiliaries shall be taken into account (see 8.1.1).

7.1.2 Thermal efficiency, heat rates or specific fuel consumption (see 6.3 and 6.4)

7.1.3 Essential protective devices

7.1.3.1 Emergency overspeed trip

No adjustment of the emergency overspeed trip setting shall be permitted during the acceptance test.

The speed at which the overspeed trip operates can be determined when the turbine is running without load. This may be carried out by adjusting the governor setting or linkage to bring the turbine slowly to sufficient speed. The speed shall be caused to increase at a rate no higher than 1 % per 5 s. The speed shall be measured with a maximum error not exceeding $\pm 0,25$ %.

During any emergency governor test, precautions shall be taken to ensure that the turbine will not exceed the maximum safe speed stated by the manufacturer.

7.1.3.2 Flame failure trip, if installed

Owing to the different types of flame failure protective devices, no universally applicable method can be specified. If, however, a direct flame viewing device is used, flame illumination may be interrupted artificially.

7.2 Optional tests

7.2.1 Governing system

7.2.1.1 Constant speed regulation

During these tests, the only governor adjustment shall be that initially required for establishing the rated speed at corresponding rated power outputs. Under these conditions, and depending upon agreement between the parties to the test on the purpose and nature of testing, one or more items from the following subdivisions may be determined :

a) maximum and minimum manually or remotely adjustable sustained governed speeds at no load;

b) permanent and momentary speed variation :

The speed variation test is accomplished with the turbine working at rated speed under specified operating conditions, by rejecting instantaneously "rated full load" and noting the maximum transient and permanent speed rise. The (average) droop in per cent is expressed as the ratio of the permanent speed rise to the speed at rated load.

The maximum transient speed may be expressed as a percentage of the rated speed.

Stabilization time is defined as the interval between the instant of rejecting the load and the instant when the speed remains within 0,5 % of the permanent no-load speed. In applications where sudden load acceptance is important, the transient minimum speed reached shall be measured together with the recovery time defined as the difference between the instant of load application and the moment when a difference of no more than 0,5 % of the permanent speed is attained;

c) dead band :

The dead band is the total magnitude of the change in steady speed within which there is no resulting measurable change in the position of the fuel control valve. It is a measure of the insensitivity of the speed governor and is expressed in per cent of rated speed.

7.2.1.2 Variable speed regulation

a) General stability of the governed speed control at given settings, including idling settings, within the region of operation as given in 7.2.1.2 b).

Stability can be defined as a condition where no sustained oscillations or fluctuations occur in the load or speed owing to causes within the control of the governor control loop.

b) Maximum and minimum manually or remotely adjustable sustained governed speed, at an appropriate load.

c) Maximum momentary increase in the governed speed above the rated speed when the fuel control setting or gas regulating valve is suddenly shifted from the idling to the rated speed position under conditions of no load.

d) Maximum momentary decrease in the governed speed below the idling no-load speed when the fuel nozzle or gas regulating valve is suddenly shifted from the rated speed position at steady-state rated power output to the idling no-load setting.

e) Dead band. (See 7.2.1.1 c).)

7.2.1.3 Temperature control

If temperature regulation is specified, the effectiveness of the system shall be checked by determining the specific limits of the gas turbine exhaust or turbine inlet temperature at specified loads or of other limiting temperatures.

7.2.2 Protective devices

7.2.2.1 Low lubricating oil pressure

The complete system may be tested by artificially subjecting the sensing device to a reduction of input pressure whilst the machine is in operation.

Alternatively, where there is a main shaft driven pump, the output of this shaft driven pump may be decreased by reducing the speed of the machine until the pressure reaches the initiating level. It may be necessary to inhibit the starting of the main standby pump(s) to reach the lower alarm-tripping levels.

7.2.2.2 High lubricating oil temperature

The cooling of the lubrication oil may be inhibited until the initiating temperature is reached. Alternatively, the complete system may be tested by subjecting the sensing head to the required temperature limits using external means.

7.2.2.3 High bearing metal temperature

Because of the different means of sensing temperature it is not possible to be specific. It is preferable to increase the temperature either by injecting the required signal or by removing the sensing head and applying heat to it externally until the actual set temperature is reached. If this is not possible, the trip shall be proved by lowering the setting to coincide with the actual running temperature. In the latter case, it is essential to prove that the tripping device operates satisfactorily on the bench when the actual "as set" temperature is reached.

7.2.2.4 Fuel supply pressure

The supply pressure may be changed by adjustment until it is at the tripping level.

7.2.2.5 Turbine overtemperature

Because of the different means of sensing temperature, it is not possible to be specific. It is preferable to simulate the increase in temperature, for example, by reducing the appropriate pneumatic signal or by injecting the required voltage signal. If this is not possible, the trip shall be operated by lowering the setting to coincide with the running temperature. In the latter case, it is essential that the tripping device operates satisfactorily on the bench when the actual "as set" temperature is reached.

7.2.3 Handling characteristics

7.2.3.1 Starting sequence

Determination of the starting sequence will require a test log with notations concerning times of significant events in the starting cycle. A stop-watch or conventional synchronous-motor clock should provide adequate accuracy. For either manual or automatic starting sequences, parties to the test shall reach prior agreement on the method of indicating significant events in the starting sequence. A typical starting test log could consist of recording the time and the speed at which significant events occur such as initial start signal, light-up, starter-off, and attainment of idling speed.

7.2.3.2 Starting reliability

Starting reliability shall have been attained when ten consecutive successful starts are performed in accordance with operating instructions supplied with the unit. Test runs during the normal course of commissioning may be taken into account provided the runs are consecutive. The test log will record the total number of consecutive attempts to start, with indication of events, and will identify the successful starts among the attempts.

Where possible, the machine condition prior to starts will be varied to include starts after long shut-down periods and starts immediately, after stopping.

7.2.3.3 Special starting characteristics

Subject to agreement by the parties to the test, determination of starting characteristics may be extended to include tests of one or more of the following :

- a) black start : no available power external to the installation;
- b) remote start i.e. by cable, pilot wire, microwave or carrier current;
- c) emergency start;
- d) dead load pick-up;
- e) alternate fuel start on dual fuel machines;
- f) starting power requirements;
- g) minimum self-sustaining speed determination;
- h) starting fuel consumption.

7.2.3.4 Normal load pick-up

The capability and reliability of load pick-up shall be proved with a minimum of two and a maximum of five tests, of which at least one must be made from cold. These tests may be performed as part of any of the successful starts in 7.2.3.2. These tests shall be performed in accordance with the operating instructions.

7.2.4 Amplitude of vibration

Test methods are subject to agreement between the parties to the test, in particular with regard to the following points :

- a) location of measurement; vibration of bearing casings or displacement of shaft(s);
- b) instrumentation : use of pick-ups measuring acceleration or displacement speed or displacement itself.

7.2.5 Stack emission

Tests shall be performed in accordance with a recognized or mutually agreed test method for stack emission.

7.2.6 Exhaust mass flow and temperature (for waste heat recovery evaluation)

Exhaust mass flow is determined either by direct measurement of airflow and fuel-flow in accordance with 6.7 or by indirect means (heat balance, 8.5). Turbine outlet temperature is determined according to 6.5.2.

7.2.7 Noise level

Test methods are subject to agreement between parties to the test, in particular with regard to the following points:

- location of measuring points;
- instrumentation;
- correction for background noise.

It is recommended that the tests and procedures used should be in accordance with a recognized test specification, for example ISO/R 495.

7.2.8 Thermal discharges

Tests shall be performed in accordance with a recognized or mutually agreed test method¹⁾ for thermal discharge.

Thermal discharge is the discharge of heat from the gas turbine by such means as radiation, convection, cooling water, exhaust gas, etc., to the surrounding environment. The total quantity of rejected heat, temperature rise of coolant and temperature of the coolant discharge may be important in certain cases.

8 COMPUTATION OF RESULTS

In computing results of tests for power and thermal efficiency, the determination may be made with averaged or integrated values of observations made during a single test run, after applying corrections for instruments, etc., as presented in this International Standard.

8.1 Power output

8.1.1 Net shaft power output, mechanical

When the torque is measured at the power take-off connection, the gross shaft mechanical power output is given by the formula:

$$P_{gr} = M\omega$$

where

P_{gr} is the gross shaft power output, in kilowatts;

M is the torque, in kilonewton metres;

ω is the angular velocity, in radians per second, given by

$$2\pi \frac{n}{60}$$

n being the speed, in revolutions per minute.

Values in this equation will be measured in accordance with 6.3. If separately driven auxiliaries or other accessories requiring power are included with the engine assembly, a correction shall be made to obtain net shaft power. Debits and credits are calculated on the basis of net shaft power output of the auxiliaries except when these are driven electrically, in which case the measured electrical input shall be used. With regard to the auxiliaries, which are not continually in use during normal operation, the power they absorb shall not be taken into account (i.e. air compressor for starting, auxiliary oil-pump, etc), except for the charging compressor in a closed cycle turbine, in which case absorbed power shall be taken into account.

Debits and credits may be made as in the following example.

Debits

(Deduct from measured gross shaft output)

- 1) Separately driven fuel, lubricating or water pump, which is part of the engine system.
- 2) Separately driven compressors, such as charging compressors for closed cycle or supercharging compressors for open cycle.
- 3) Separately driven fuel gas booster compressor, when it is part of the engine assembly.
- 4) Separately driven fans for cooling purposes including cooling tower, if used.
- 5) External power for heating fuel.

Credits

(Add to measured gross shaft output)

- 1) Air bleed for station auxiliary supply or chemical process that is not part of engine assembly.
- 2) Auxiliary electric generator driven by engine, but forming no part of engine assembly.
- 3) Mechanical or hydraulic auxiliary drive, but forming no part of engine assembly.

8.1.2 Net power output, electrical

Where power output is determined from electrical measurements of an engine driven generator unit, the measured electrical power output at the generator terminals will be the resultant sum of the electrical power output measurements plus cable or other losses between the generator terminals and switchboard, if any, less that portion of separately supplied excitation power and/or generator ventilation power as indicated in 6.3.2.

If separately driven auxiliaries, or other accessories requiring power, are included with the engine assembly, debits and credits are calculated following the procedure given in 8.1.1.

1) Further International Standards concerning methods of testing stack emission, noise emission, and thermal discharges from gas turbines will be prepared.

8.1.3 Conversion from electrical to mechanical power outputs

In order to convert electrical power output to mechanical power output at the output shaft connection, the net electrical power output is divided by the product of the efficiencies of the generator and of the main transmission gearing when used. The generator and gear efficiencies may be determined at the relevant conditions of load and power factor from performance information furnished by their respective manufacturers. On the basis of this information, curves of generator and gear efficiencies shall be plotted against electrical power output.

In the event that performance information is not available for the generator, its losses may be determined in accordance with the IEC Publication 34-2.

8.2 Heat consumption and thermal efficiency

8.2.1 Heat consumption

The rate of heat consumption is determined by the equation :

$$q_r = \frac{m_\tau (Q_{L0} + h_{f4} - h_0)}{\tau} = m (Q_{L0} + h_{f4} - h_0)$$

where

q_r is the rate of heat consumption, in kilowatts;

τ is the duration of test, in seconds;

m_τ is the mass of fuel used during period τ , in kilograms;

Q_{L0} is the lower calorific value of the fuel at 15 °C and constant pressure, in kilojoules per kilogram;

m is the rate of fuel consumption, in kilograms per second, given by $\frac{m_\tau}{\tau}$;

h_{f4} is the specific enthalpy of the fuel at temperature T_{f4} , entering the heat source (combustion chamber), in kilojoules per kilogram;

h_0 is the specific enthalpy of the fuel at 15 °C, in kilojoules per kilogram.

8.2.2 Thermal efficiency

The thermal efficiency of the engine based on net shaft power output may be computed from :

$$\eta_t = \frac{P}{q}$$

where

η_t is the thermal efficiency;

P is the net shaft power output, in kilowatts;

q is the heat consumption, in kilowatts.

8.2.3 Heat rate

The heat rate may be computed from

$$q_p = \frac{q}{P} = \frac{1}{\eta_t}$$

where

q_p is the heat rate, in kilowatts of heat per kilowatt of power;

q is the heat consumption, in kilowatts;

P is the net shaft power output, in kilowatts.

8.3 Corrections of test results to reference conditions

8.3.1 The primary object of this International Standard is stated in 1.1. The preferred approach in conducting tests is to run at the reference conditions of compressor inlet (temperature, pressure, and relative humidity), and at the standard exhaust as defined in 3.3. It is recognized however that this may not always be possible; the tests may have to be run at some other conditions, and the results corrected to reference conditions to facilitate comparison of power and thermal efficiency.

8.3.2 The basic approach for conducting the tests is to operate the gas turbine engine at the same aerodynamic conditions for the actual compressor inlet conditions as would occur if the gas turbine engine were operating at rated load at reference conditions. This will result in both the compressor and turbine being at the correct point on their efficiency curves. To duplicate these conditions, the actual turbine exhaust temperature and speed will be lower than reference if the compressor inlet temperature is lower than the reference condition.

Conversely, it would be necessary to run above reference exhaust temperature and speed if the compressor inlet temperature exceeded the reference value. Therefore from a practical standpoint, the performance tests should preferably be run when ambient conditions allow the tests to be conducted at a compressor inlet temperature equal to, or lower than, the reference conditions. For example this may necessitate running the tests at night during hot weather.

In practice, the above principles are subject to the limitations associated with the type of machine used (8.3.4).

8.3.3 Variable speed turbines

In the case of an installation involving variable speed characteristics, such as mechanical drive, the corrections shall be made as follows :