70

INTERNATIONAL STANDARD

ISO 3046-2

Second edition
1987-11-01

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ORGANISATION INTERNATIONALE DE NORMALISATION
МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Reciprocal internal combustion engines — Performance —

Part 2: Test methods

Moteurs alternatifs à combustion interne — Performances —

Partie 2: Méthodes d'essai

Reference number
ISO 3046-2 : 1987 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 3046-2 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines.*

This second edition cancels and replaces the first edition (ISO 3046-2 : 1977), of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Printed in Switzerland

Contents

Page

1 Scope 1

2 Field of application 1

3 References 1

4 Definitions 1

5 Designation of tests 1

6 Extent of tests 1

7 Test conditions 2

8 Power correction method 5

9 Measurement techniques 6

10 Test procedures 6

11 Test report 8

Annexes

A Examples of power adjustment, specific fuel consumption adjustment and simulation of high on-site ambient temperature for adjusted engines with adjusted fuel settings 10

B Examples of power correction for non-adjusted engines (engines with pre-set fuel settings) 13

Reciprocal internal combustion engines — Performance —

Part 2: Test methods

1 Scope

This part of ISO 3046 specifies acceptance and type test methods for reciprocating internal combustion engines in commercial production. Where necessary, individual requirements are given for particular engine applications.

2 Field of application

This part of ISO 3046 covers reciprocating internal combustion engines for land, rail-traction and marine use, excluding engines used to propel agricultural tractors, road vehicles and aircraft.

This part of ISO 3046 may be applied to engines used to propel road construction and earth-moving machines, industrial trucks and for other applications where no suitable International Standard for these engines exists.

This part of ISO 3046 may be applied to tests on a test bed at the manufacturer's works and to tests on site (see 7.1.4).

3 References

ISO 3046, *Reciprocating internal combustion engines — Performance —*

Part 1: Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption.

Part 3: Test measurements.

Part 4: Speed governing.

Part 5: Torsional vibrations.

Part 6: Overspeed protection.

4 Definitions

For the purposes of this part of ISO 3046, the following definitions apply.

4.1 acceptance test: Test carried out as an overall check on the manufacturing quality, and to establish that the contractual commitments have been fulfilled.

4.2 type test: Test carried out on representative engines of a certain engine type to establish the main performance data of the engine and, as far as possible, to enable their reliability and durability in service to be assessed.

4.3 special test: Test additional to acceptance or type tests carried out to meet the requirements of inspecting and legislative authorities, Classification Societies or customers.

NOTE — Special tests are subject to agreement between the manufacturer and customer.

4.4 power adjustment: Calculation procedure by which a power at one set of ambient conditions is modified to represent the power expected under another set of ambient conditions. Power adjustment may require engine adjustment. (See 4.6 and 7.2.1.)

4.5 power correction: Calculation procedure by which a power determined under engine test conditions is modified so that it represents the power expected under other operational or reference conditions without any engine adjustment.

4.6 engine adjustment: Physical procedure of modifying an engine for the purpose of adapting it to a different set of ambient conditions, such as by moving the limiting fuel stop, re-matching the turbocharger, changing the fuel injection timing or other mechanical changes.

5 Designation of tests

This part of ISO 3046 gives two test categories: reference may be made to the relevant category of test as follows:

— ISO 3046-2 — A (for acceptance tests; see 10.1);

— ISO 3046-2 — T (for type tests; see 10.2).

6 Extent of tests

6.1 The programme of acceptance and type tests shall be established by the manufacturer.

6.2 It is the responsibility of the manufacturer to define the extent of measurements, which shall be agreed with the customer. Table 1 may be taken as a guide for selecting the engine groups appropriate to the test measurements given in list A (see table 2).

Table 1 — Measurement selection guide

Engine group number	Typical characteristics of engine group
1	Engines the operating conditions of which are not measured in service, usually with maximum design speeds of more than 1 800 min^{-1}
2	Naturally aspirated engines with maximum design speeds of approximately 1 500 min^{-1} and above
3	Pressure-charged engines with maximum design speeds of approximately 1 500 min^{-1} and above
4	Engines with maximum design speeds of approximately 250 to 1 500 min^{-1}
5	Engines with maximum design speeds up to 250 min^{-1}

6.3 For mass-produced engines not all tested on load, an adequate inspection procedure may be used instead of a full acceptance test.

6.4 Dependent on the test categories and the engine group number, five lists of recommended test measurements, calculated values and functional checks (lists A, B, C, D, E) are given in clause 10.

7 Test conditions

7.1 General

7.1.1 Before an engine test, the manufacturer shall submit the necessary technical documentation concerning the engine type and application, when mutually agreed between the manufacturer and the customer.

7.1.2 A period of running-in and preliminary tests considered adequate by the manufacturer shall precede the acceptance or type test.

7.1.3 The measurements for an acceptance or type test shall be carried out only when the engine has reached stable operating conditions as specified by the manufacturer.

7.1.4 Unless otherwise agreed between the manufacturer and the customer, tests shall be carried out on a test bed at the manufacturer's works.

7.1.5 Tests shall be carried out on the engine equipped with dependent auxiliaries necessary for its operation either supplied with the engine or belonging to the test bed equipment.

7.1.6 Test bed equipment may be used, provided that the contractual requirements are fulfilled.

7.1.7 Only those engines which are supplied with built-in transmission systems (for example, hydraulic mechanisms, reversing couplings) or electric generators, and which cannot be tested separately, need to be tested with the transmission systems or generator coupled to the engine.

If engines are tested with coupled driven machinery or a transmission system which is separable, then any variation in power, due to these coupled items, shall be eliminated from a power declared in accordance with ISO 3046-1.

7.1.8 If the acceptance test is carried out on site and the rated power at the corresponding speed cannot be verified or achieved, due to the special circumstances of the installation and/or situation of the installation, the manufacturer and the customer shall accept the test report of the test on the manufacturer's works test bed as valid, and verify only

— the declared speed at a power other than the rated power; or

— the rated power at a speed other than the rated speed.

In either case the measurement of the fuel consumption shall be omitted.

7.1.9 During tests on the engine no additional measures, other than those required to maintain the test conditions and those required for normal operation as given in the working manual, may be made.

7.1.10 The only interruptions in testing permitted are those necessary for engine maintenance as given in the working manual. In all other cases, if an interruption should occur caused by some defect of parts of the engine, the decision on whether to repeat the tests partially or entirely shall be agreed between the manufacturer and the customer.

7.1.11 The standard reference conditions and declarations of power, fuel and lubricating oil consumption shall be as specified in ISO 3046-1.

7.1.12 In cases where it is not possible to maintain the specified ambient conditions and the fuel or fluid properties for the acceptance or type test, the influence of the differing conditions and/or properties and the necessary correction of test results shall be subject to agreement between the manufacturer and customer.

NOTE — In dual-fuel engines the acceptance test is carried out with liquid fuel. An additional acceptance test with gaseous fuel may be stipulated by agreement if gaseous fuel is available at the manufacturer's works with approximately the same ignition characteristic as the gaseous fuel available on site.

In the case of spark-ignition gas engines and pilot injection gas engines, the acceptance test may be carried out at the manufacturer's works only if the composition and ignition characteristics of the gaseous fuel available are approximately the same as those of the gaseous fuel used on site.

If the acceptance test must be carried out on the basis of a special agreement at the manufacturer's works with a gaseous fuel with chemical values and properties differing significantly from those on site, the test can be made at agreed values of rated power, rated speed and fuel consumption by resetting the engine accordingly. In such a case a readjustment of the engine is necessary for the engine operation with the contractually specified gaseous fuel which is used on site.

7.2 Power adjustment, specific fuel consumption adjustment and power correction

These procedures will be carried out to determine

— whether the values of power and fuel consumption attained under engine test ambient conditions correspond to the declared values;

— the permissible maximum power under test ambient conditions to prevent the engine overloading which excess air allows.

Two possible cases are recognized:

a) Adjusted engines, where the power is adjusted to control the limiting performance parameters when the ambient conditions differ from the standard reference conditions (*e.g. to maintain an approximately constant thermal and/or* mechanical load on critical engine components). (See 7.2.1.)

b) Non-adjusted engines, where the fuel settings are pre-set, so the power and performance parameters may vary as a function of ambient conditions. (See 7.2.2.)

7.2.1 Adjusted engines

The test power may be determined, using the formulae in ISO 3046-1 where necessary, in one or more of the following ways:

a) By adjusting the ISO power from standard reference conditions to test ambient conditions.

b) By adjusting the declared service power from the site ambient conditions to the power under test ambient conditions.

c) By making the test power equal to the declared service power and testing under conditions altered artificially according to 7.2.1.4 to simulate the site ambient conditions.

d) By testing under conditions simulating some of the site ambient conditions according to 7.2.1.4 and adjusting the declared service power to allow for the remaining differences.

NOTE — Power adjustment by using formulae from ISO 3046-1 is only permissible if the turbocharging equipment or timing of the engine is not changed or modified for site ambient conditions.

7.2.1.1 When adjusting the power, the engine manufacturer shall specify which of the formulae given in ISO 3046-1 : 1986, table 1, shall be used.

If there is no suitable formula for power adjustment in ISO 3046-1, the method of adjustment shall be agreed in writing by the manufacturer and the customer.

7.2.1.2 If a turbocharged engine at the declared power and under the standard reference conditions attains neither the turbocharger speed limit nor the exhaust gas temperature limit at the turbine inlet, the manufacturer may declare substitute reference conditions as specified in ISO 3046-1 for the power adjustment.

7.2.1.3 When adjusting the site-declared power for test ambient conditions, results may be attained where for example the maximum combustion pressure in the engine cylinder exceeds the permitted value. In this case the engine test shall be carried out at such a power considered safe by the manufacturer, at which the permitted value is not exceeded.

The values of the engine parameters corresponding to the required power may be extrapolated from the measured values by a method to be agreed between the manufacturer and the customer.

7.2.1.4 Engine tests may be carried out under ambient conditions created artificially to simulate site ambient conditions: the following methods may be used:

a) Throttling of the engine (turbocharger) inlet with simultaneous depression at the outlet and in the crankchamber by an extractor device. Maximum vacuum shall not exceed the limits set by the turbocharger manufacturer.

b) Increasing the air temperature at the engine inlet by artificial heating.

c) Altering the coolant temperature at the inlet of the charge air cooler, etc.

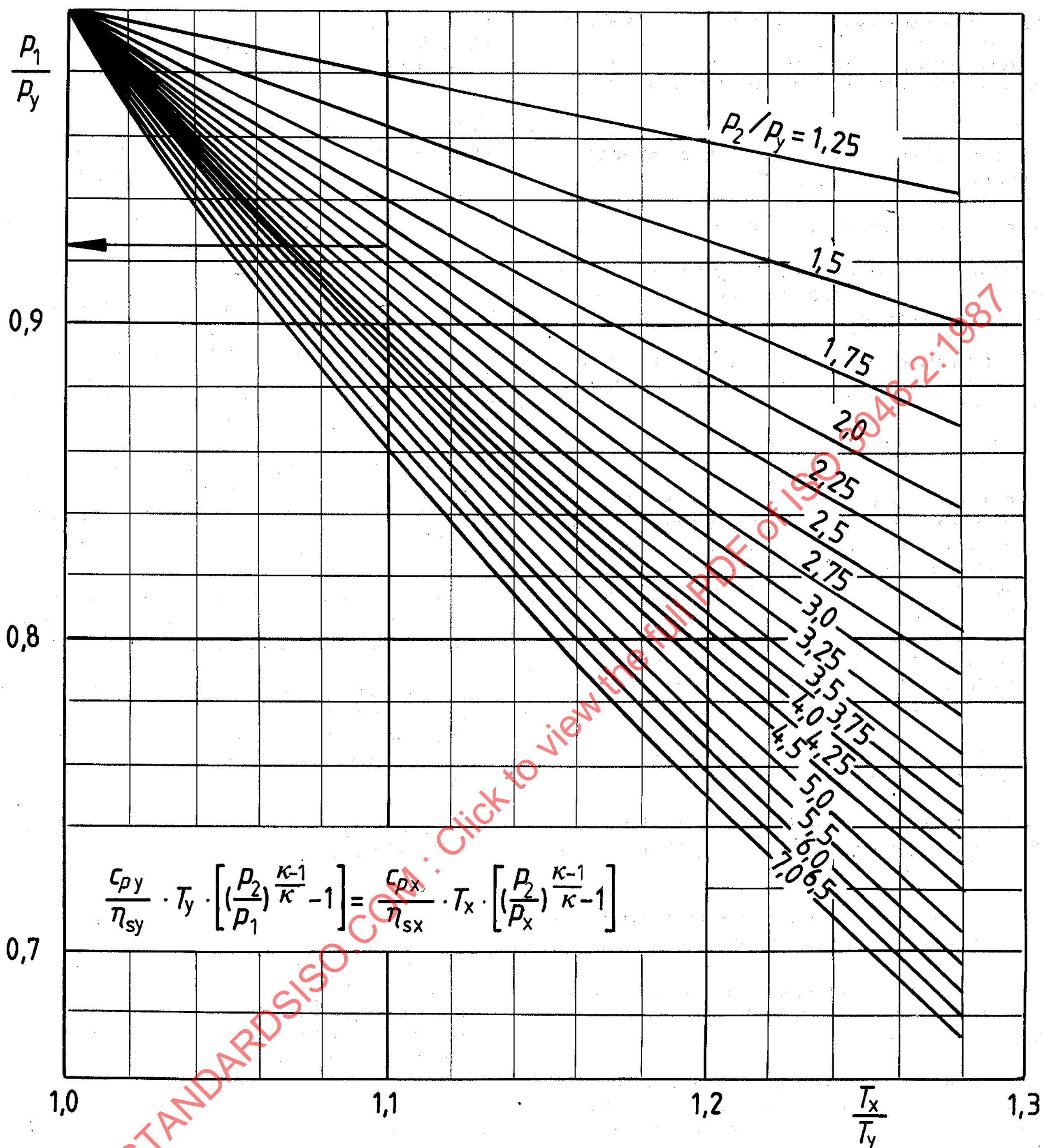
d) On pressure-charged engines having a charge air cooler, the effect of increased ambient temperature can be easily simulated by throttling at the turbocharger inlet and controlling the air temperature after the charge air cooler to be the same as that on site. The throttle ratio can be determined using figure 1.

NOTE — Examples illustrating how power adjustment, specific fuel consumption adjustment and simulation of high on-site ambient temperature are applied when testing are given in annex A.

7.2.2 Non-adjusted engines (engines with pre-set fuel settings)

Where the test conditions differ from the standard reference conditions, the method in clause 8 may be used for power correction of measured power to standard reference conditions (correction by calculation).

7.2.3 The manufacturer shall specify which method (power adjustment or power correction) is applicable to his engine with respect to 7.2.4.



p_y is the test ambient air pressure
p_x is the site ambient air pressure
p_1 is the air pressure after throttle
p_2 is the air pressure at the compressor outlet
T_y is the test ambient air temperature
T_x is the site ambient air temperature
κ is the adiabatic index
c_{py} is the test specific heat capacity at constant pressure
c_{px} is the site specific heat capacity at constant pressure
η_{sy} is the test adiabatic compressor efficiency
η_{sx} is the site adiabatic compressor efficiency
Δh_y is the test specific enthalpy difference
Δh_x is the site specific enthalpy difference

NOTES

1 Example 2 in clause A.2 of annex A provides an example of the application of figure 1.

2 The following conventional assumptions are made:

- equal compressor work;
- equal pressure at the compressor outlet;
- equal charge air temperature after cooler;
- equal air consumption through compressor;
- difference between c_{py} and c_{px} is neglected;
- adiabatic compressor efficiency is taken constant.

Figure 1 — Determination of depression at compressor inlet when simulating high on-site air temperature

7.2.4 In general the power and specific fuel consumption shall be adjusted or corrected, if any of the ambient conditions under which the engine operates during test or on site differ from the standard reference conditions. The amount by which the test ambient conditions may differ from the standard reference conditions without affecting the power and the specific fuel consumption depends for example on the engine design, air excess, engine speed and its thermal load. In such cases the engine manufacturer shall indicate the specific amounts by which the test or site ambient conditions may differ from the standard reference conditions without the necessity of adjusting or correcting the power and the specific fuel consumption.

8 Power correction method

The power correction method has been verified by tests on a representative number of engines with pre-set settings and engine speeds of 2 000 min^{-1} and above. Manufacturers may extend this method to other engines as considered appropriate, or restrict it, if justified by experience.

The power correction factor α is a factor by which the observed (determined) power shall be multiplied to determine the engine power under the standard reference conditions specified in ISO 3046-1. The power corrected to the standard reference conditions P_r may be calculated as follows:

$$P_r = \alpha_a \times P_y \text{ (for spark-ignition engines)}$$

or

$$P_r = \alpha_d \times P_y \text{ (for compression-ignition engines)}$$

where

P_y is the power observed (determined) on the test bed;

α_a is the correction factor for spark-ignition engines;

α_d is the correction factor for compression-ignition engines.

NOTES

1 Tests may be carried out in air-conditioned test rooms so that the atmospheric conditions may be controlled.

2 Examples illustrating how correction factors are applied when testing engines with pre-set fuel settings are given in annex B.

8.1 Correction factor α_a for spark-ignition engines

The correction factor α_a is calculated from the following equation[1]:

$$\alpha_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)^{1,2} \left(\frac{T_y}{T_r}\right)^{0,6}$$

where

T is the absolute air temperature in kelvins at the air inlet to the engine;

p is the total barometric pressure in kilopascals;

p_s is the saturated water vapour pressure in kilopascals at the applicable temperature (at ϕ = 100 %);

ϕ is the relative humidity.

Subscript r corresponds to values under standard reference conditions.

Subscript y corresponds to values under test ambient conditions.

This formula is only applicable if the correction factor α_a is between 0,93 and 1,07, the ambient temperature at the air inlet to the engine is $T_r \pm 10$ °C and the dry barometric pressure is 80 to 110 kPa. If these limits are exceeded the corrected value obtained shall be given, and the test ambient conditions (temperature and pressure) precisely stated in the test report.

8.2 Correction factor α_d for compression-ignition engines

The power correction factor α_d for compression-ignition engines with pre-set fuel settings is obtained by the following equation:

$$\alpha_d = (f_a)^{f_m}$$

where

f_a is the atmospheric factor;

f_m is the engine factor (characteristic parameter for each type of engine).

8.2.1 Atmospheric factor f_a

This factor indicates the effect of environmental conditions (pressure, temperature and humidity) on the air drawn in by the engine. The atmospheric factor equation differs according to the type of engine.

For naturally aspirated and mechanically pressure-charged engines, the following equation applies:

$$f_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right) \left(\frac{T_y}{T_r}\right)^{0,7}$$

1) In the case of engines fitted with automatic air temperature control, if the device is fully closed at full load at 25 °C (no heated air added to the intake air) the test is carried out with the device fully closed and the normal correction factor applied. If the device is still operating at 25 °C then the test is made with the device operating normally and the exponent of the temperature term in the correction factor may be taken as zero (no temperature correction).

For turbocharged engines with or without charge air cooling, the following equation applies:

$$f_a = \left(\frac{p_r - \phi_r p_{sr}}{p_y - \phi_y p_{sy}}\right)^{0,7} \left(\frac{T_y}{T_r}\right)^{1,5}$$

NOTE — For symbols and subscripts, see 8.1.

8.2.2 Engine factor f_m

This factor is dependent upon the type of engine and the trapped air/fuel ratio corresponding to the fuel setting.

The engine factor f_m is a function of q_c as follows:

$$f_m = 0{,}036\, q_c - 1{,}14$$

in which

$$q_c = \frac{q}{\pi}$$

where

q is the fuel delivery per cycle measured in milligrams per litre of engine swept volume;

π is the ratio of absolute pressure of compressor outlet to that of compressor inlet.

NOTE — For 2-stage turbocharging, this will be the overall pressure ratio (π = 1 for naturally aspirated engines).

This formula is valid for the following value interval, in milligrams per litre cycle, of q_c:

$$40 \leqslant q_c \leqslant 65$$

For q_c values lower than 40, a constant value of f_m equal to 0,3 (f_m = 0,3) will be taken. For q_c values higher than 65, a constant value of f_m equal to 1,2 (f_m = 1,2) will be taken (see figure 2).

8.2.3 Limitation in use of correction formula

The correction formula in 8.2 is only applicable where the correction factor α_d is between 0,9 and 1,1, the ambient temperature of the air inlet of the engine is $T_r \pm 15$ °C and the dry barometric pressure is 80 to 110 kPa. If these limits are exceeded the corrected value obtained shall be given and test ambient conditions (temperature and pressure) precisely stated in the test report.

9 Measurement techniques

9.1 For the methods of measurement to be used during acceptance and type tests, symbols for parameters under measurement, units, etc., refer to ISO 3046-3.

9.2 If printing or memory type measuring instruments are used, the printed and/or stored data shall be displayed during the test.

10 Test procedures

10.1 Acceptance tests

10.1.1 Acceptance tests comprise a specified sequence of power settings with measurements and calculated values given in lists A and B and the functional checks given in list C.

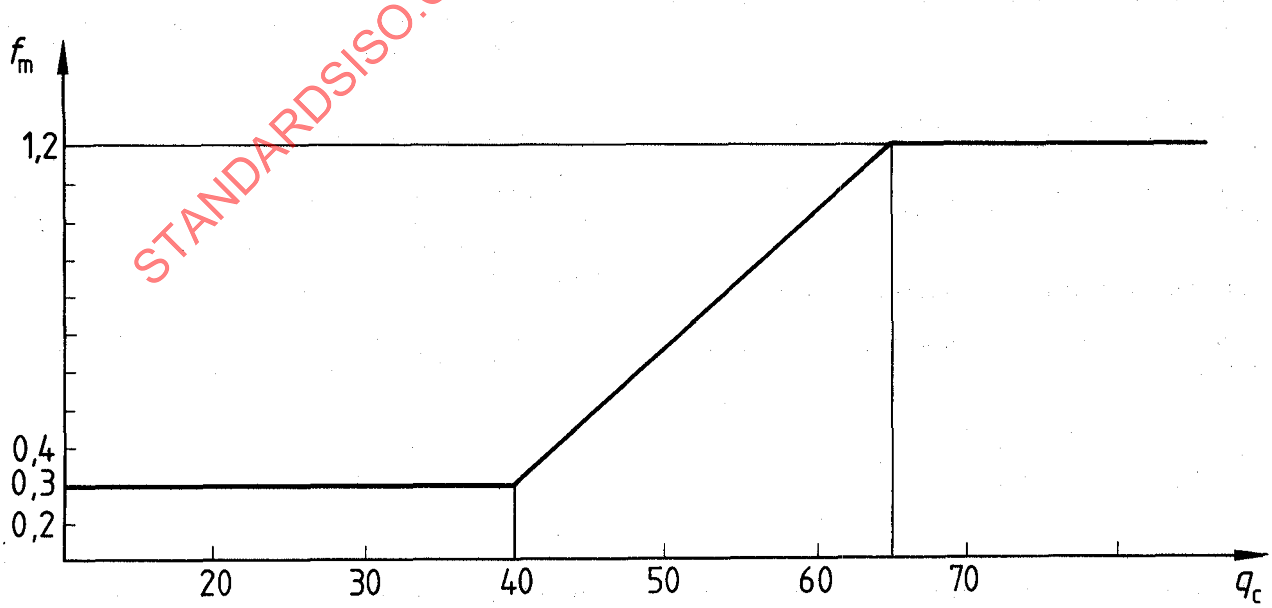


Figure 2 — Engine factor f_m as a function of the corrected fuel delivery q_c

10.1.2 The duration of the total acceptance test depends on the engine power and applications.

10.1.3 Measurements in list A normally shall be made according to the specified engine group for each operating condition wherever appropriate and where provision exists on the engine for doing so. Where measurements are carried out for the purpose of verifying the declaration of power, engine speed and fuel consumption, valid measurements shall be carried out at least twice. A measurement shall be considered valid if the variations of the engine brake torque and engine speed values in relation to the settings of the operating values do not exceed ± 2 %. The variation of the power output during this period shall not exceed ± 3 %. This requirement shall not normally apply to spark-ignition engines with a brake power less than 50 kW.

Measurements in list A are arranged in an ascending order of test measurement complexity and are presented for guidance when the contract is drawn up between the manufacturer and the customer. Either party may, by agreement, add to or delete from the measurements in list A, to suit the particular type of engine involved. Where no provision exists on the engine for a particular measurement, this shall be stated by the manufacturer.

Table 2 — List A — Test measurements

No.	Parameter to be measured	Engine group number (see table 1)				
		1	2	3	4	5
A1	Barometric pressure, humidity and ambient temperature	×	×	×	×	×
A2	Engine speed or cycle frequency	×	×	×	×	×
A3	Engine brake torque and/or	×	×	×	×	×
A4	fuel pump or governor or throttle control rod setting					
A5	Fuel consumption		×	×	×	×
A6	Lubricating oil pressure		×	×	×	×
A7	Temperature and pressure of exhaust gas leaving the engine		×	×	×	×
A8	Air intake pressure and temperature at the engine or pressure charger inlet		×	×	×	×
A9	Exhaust gas temperature at the turbine inlet			×	×	×
A10	Boost pressure in the air manifold			×	×	×
A11	Turbocharger speed			×	×	×
A12	Coolant mean temperature in and out of the cylinder block			×	×	×
A13	Lubricating oil temperature at the engine inlet and outlet			×	×	×
A14	Boost pressure drop through the charge air cooler			×	×	×
A15	Boost pressure after each charge air cooler			×	×	×
A16	Charge air temperature after each charge air cooler			×	×	×
A17	Coolant mean temperature at the charge air cooler inlet and outlet			×	×	×
A18	Maximum cylinder pressure				×	×
A19	Exhaust gas pressure at the turbine inlet			×	×	×
A20	Exhaust gas temperature of each cylinder				×	×
A21	Individual coolant circuit temperatures and pressures				×	×
A22	Lubricating oil pressure in individual circuits, e.g. turbocharger, piston cooling, etc.				×	×
A23	Lubricating oil pressure before and after filters and coolers				×	×
A24	Secondary coolant and lubricating oil temperatures in and out of heat exchangers				×	×
A25	Fuel supply pressure and temperature				×	×
A26	Compression pressure					×

NOTE — Additional items may be included by agreement between manufacturer and customer.

10.1.4 Where appropriate the manufacturer shall supply the calculated values given in list B on the basis of test measurements obtained from list A.

List B

B1 : Brake power.

B2 : Brake specific fuel consumption.

10.1.4.1 The measurement of fuel consumption shall be carried out during the measurement of power.

10.1.4.2 For engines having a brake power of 200 kW and above, if the variation between the results of two fuel consumption measurements is more than 2 %, the measurement shall be repeated for this operating condition.

10.1.4.3 Fuel fed to the engine which is surplus and not consumed shall be taken into account in the measurement accordingly.

10.1.5 Functional checks

List C comprises functional checks which may additionally be carried out on engines in groups 2 to 5 in table 1. The selection from list C shall be made by agreement between the manufacturer and the customer.

List C

Checks shall be carried out to demonstrate the following.

C1 : The correct functioning of the overspeed limiting device in accordance with ISO 3046-6.

C2 : The correct functioning of the speed governing system in accordance with ISO 3046-4.

C3 : The ability of all malfunction protection and warning devices to respond correctly to the fault conditions in which they should operate (for example, low lubricating oil pressure, high lubricating oil temperatures, high coolant temperatures, pressure rise in the engine crankcase, etc.).

C4 : The correct functioning of all automatic pressure and temperature controls.

C5 : The ability of the starting system to perform prior to and/or after the acceptance test conditions of the engine are reached, subject to agreement between manufacturer and customer.

C6 : The correct functioning of the reversing mechanism, built-in reverse reduction gear and couplings.

C7 : That the temperature of important components is satisfactory.

C8 : Crank web deflection.

C9 : Stability of the engine on its support.

C10 : The condition after test of one or more piston and cylinder assemblies and bearings chosen by inspection.

NOTE — Additional checks may be included by agreement between the manufacturer and the customer.

10.2 Type tests

10.2.1 A type test comprises a specified sequence of power/engine speed combined values, reversals and stop.

10.2.2 Type tests will include, as far as applicable, all measurements, calculations and functional checks in list A, engine group 5, and lists B and C and in addition list D as follows :

List D

D1 : Air consumption.

D2 : Lubricating oil consumption.

D3 : Dismantling, inspection and measuring of important parts subject to wear.

10.3 Special tests

Special tests are any of those in list E which may be required by inspecting authorities, Classification Societies, by legislation or by the customer.

List E — Typical examples

E1 : Torsional vibration frequencies and amplitudes at prescribed power/engine speed combinations when the engine is tested coupled to its contract driven machinery in accordance with ISO 3046-5.

E2 : Engine heat balance.

E3 : Sound level.

E4 : Exhaust gas emission characteristics.

E5 : Tests in conjunction with contract driven machinery.

E6 : Parallel running and other electrical tests of engine-driven generators.

E7 : Emergency reversal of marine engines.

E8 : Determination of minimum stable speed of marine engines.

E9 : Changeover on dual-fuel engines.

E10 : Ability to carry out maintenance tasks within the time stated by the manufacturer.

E11 : Ability to manoeuvre and provide a stated power when operating with specified malfunctions, for example with one or more turbochargers inoperative.

11 Test report

11.1 The manufacturer shall provide a test report.

11.1.1 Normally, acceptance test reports shall be provided for engine groups numbers 3, 4 and 5 only.

11.1.2 Type test reports shall be provided for all groups of engines.

11.2 The test report shall include engine identification and the following test information:

a) reference to this part of ISO 3046;

b) date, place, designation of test and inspecting authority;

c) type of fuel and lubricating oils used during tests;

NOTE — Quality of fuel:

If the fuel used complies with the specification of a national or International Standard, the properties need be verified only by explicit agreement between the manufacturer and customer.

If the fuel does not comply with the specification of a national or International Standard, the properties and constituents should be stated as agreed between the manufacturer and the customer.

The lower calorific value of the fuel and its method of determination should be stated.

d) dependent auxiliaries, engine settings and proprietary equipment;

e) table of values measured during the test;

f) interpretation of certain measurements as required.

Annex A

Examples of power adjustment, specific fuel consumption adjustment and simulation of high on-site ambient temperature for adjusted engines with adjusted fuel settings

(This annex forms an integral part of the Standard.)

A.1 Example 1

A four-stroke turbocharged compression-ignition engine with charge air cooling will develop 640 kW net brake power (P_x) under site ambient conditions, where

p_x = 70 kPa

T_x = 330 K

T_{cx} = 300 K

η_m = 0,85

What power should be developed under test ambient conditions, where

p_y = 100 kPa

T_y = 300 K

T_{cy} = 280 K

Initially, the engine power developed under site ambient conditions will be adjusted to the standard reference conditions, and then the results attained will be adjusted to test ambient conditions.

The first step in solving the example is to determine what the brake power output is at standard reference conditions.

The general equations and symbols needed to adjust the power are found in clauses 10.1 and 10.2, and equations (1), (2) and (4) of ISO 3046-1 : 1986.

The general equations shall be redefined so the site ambient conditions can be adjusted to standard reference conditions.

To adjust net brake power P_x at site ambient conditions to net brake power at standard reference conditions P_r:

$$P_x = \alpha_r P_r$$

where

P_x is the net brake power at site ambient conditions (640 kW);

α_r is the power adjustment factor for adjustment to standard reference conditions;

P_r is the net brake power at standard reference conditions.

The power adjustment factor α_r for adjusting site ambient conditions to standard reference conditions is

$$\alpha_r = k_r - 0{,}7\,(1 - k_r)\left(\frac{1}{\eta_m} - 1\right)$$

where

k_r is the ratio of indicated power for adjustment from site ambient to standard reference conditions;

η_m is the mechanical efficiency (0,85).

The power ratio k_r needed for adjustment from site ambient conditions to standard reference conditions is

$$k_r = \left(\frac{p_x}{p_r}\right)^m \left(\frac{T_r}{T_x}\right)^n \left(\frac{T_{cr}}{T_{cx}}\right)^q$$

where

k_r is the ratio of indicated power for adjustment from site ambient to standard reference conditions;

p_r is the standard reference total barometric pressure (100 kPa);

T_r is the standard reference absolute air temperature (298 K);

T_{cr} is the standard reference absolute charge air coolant temperature (298 K);

p_x is the total barometric pressure at site (70 kPa);

T_x is the ambient air temperature at site (330 K);

T_{cx} is the charge air temperature at site (300 K);

m, n and q are exponents found in 3046-1 : 1986, table 1 :

m = 0,7

n = 1,2

q = 1,0

Using the formulae that have been developed and substituting the values given in the example:

$$k_r = \left(\frac{70}{100}\right)^{0,7} \left(\frac{298}{330}\right)^{1,2} \left(\frac{298}{300}\right)^{1,0} = 0,684$$

$$\alpha_r = 0,684 - 0,7\,(1 - 0,684)\left(\frac{1}{0,85} - 1\right)$$

$$= 0,684 - (0,7 \times 0,316 \times 0,18)$$

$$= 0,644$$

Therefore the power, in kilowatts, is

$$P_r = \frac{640}{0,644} = 994$$

This is the power output at standard reference conditions.

The next step is to adjust the power to test ambient conditions, where

P_y is the power under test ambient conditions;

p_y is the total barometric pressure at test ambient conditions;

T_y is the air temperature at test ambient conditions;

α_y is the power adjustment factor for adjustment from standard reference to test ambient conditions;

k_y is the ratio of indicated power for adjustment from standard reference to test ambient conditions.

The formulae for adjusting from standard reference conditions to test ambient conditions are

$$P_y = \alpha_y P_r$$

$$\alpha_y = k_y - 0,7\,(1 - k_y)\left(\frac{1}{\eta_m} - 1\right)$$

$$k_y = \left(\frac{p_y}{p_r}\right)^m \left(\frac{T_r}{T_y}\right)^n \left(\frac{T_{cr}}{T_{cy}}\right)^q$$

Substituting,

$$k_y = \left(\frac{100}{100}\right)^{0,7} \left(\frac{298}{300}\right)^{1,2} \left(\frac{298}{280}\right)^{1,0} = 1,056$$

$$\alpha_y = 1,056 - 0,7\,(1 - 1,056)\left(\frac{1}{0,85} - 1\right)$$

$$= 1,056 + (0,7 \times 0,056 \times 0,18) = 1,063$$

Therefore the power, in kilowatts, is

$$P_y = 1,063 \times 994 = 1\,057$$

If there is a limitation in the maximum allowable combustion pressure, say, at 808 kW, and the manufacturer so decides, the engine shall be tested under loads up to but not exceeding 808 kW. When defining factors k and α, the tables in the annexes of ISO 3046-1 may be used.

A.2 Example 2

The engine from example 1 is required to be tested under conditions simulating site ambient conditions, for example at a higher test ambient temperature T = 330 K and a pressure ratio $\frac{p_2}{p_y}$ of 2,5. Using the inlet air throttling method, determine what power must be developed on the test bed and the pressure behind the throttle plate necessary to simulate the site ambient conditions.

In simulating the higher test ambient temperature using the throttling method, the air temperature after the charge air cooler will be equal to that reached under site ambient conditions. The temperature or coolant flow control at the charge air cooler inlet shall be adjusted accordingly.

Using clauses 10.1 and 10.2, and equations (1), (2) and (4) of 3046-1 : 1986 the simulated power can be calculated accordingly:

$$P_y = \alpha_y P_x$$

where

P_y is the power to be developed on the test bed;

α_y is the power adjustment factor for simulating site ambient conditions on the test bed;

k_y is the ratio of indicated power for simulating site ambient conditions on the bed.

The ratio of indicated power for the example would be

$$k_y = \left(\frac{p_y}{p_x}\right)^m \left(\frac{T_x}{T_y}\right)^n \left(\frac{T_{cx}}{T_{cy}}\right)^q$$

Because in using the throttling method the test bed air temperature after the charge air cooler equals that of the site, the last two terms become equal to one, so the resulting equation becomes

$$k_y = \left(\frac{p_y}{p_x}\right)^m$$

where

p_y is the test ambient pressure;

p_x is the site ambient pressure.

Substituting the given values

$$k_y = \left(\frac{100}{70}\right)^{0,7} = 1,284$$

The power adjustment factor would be

$$\alpha_y = k_y - 0{,}7\,(1 - k_y)\left(\frac{1}{\eta_m} - 1\right)$$

Substituting the given values

$$\alpha_y = 1{,}284 - 0{,}7\,(1 - 1{,}284)\left(\frac{1}{0{,}85} - 1\right)$$

$$= 1{,}284 + (0{,}7 \times 0{,}284 \times 0{,}18)$$

$$= 1{,}320$$

Using the calculated values, the power output, in kilowatts, to be measured on the test bed becomes

$$P_y = 1{,}320 \times 640 = 845$$

To determine what the pressure behind the throttle plate must be to simulate site ambient conditions, figure 1 is used, where

$$\frac{T_x}{T_y} = \frac{330}{300} = 1{,}10$$

Using this value and the given pressure ratio $\frac{p_2}{p_y} = 2{,}5$ the value for $\frac{p_1}{p_y}$ from figure 1 is $\frac{p_1}{p_y} = 0{,}925$

The air pressure p_1 after the throttle, in kilopascals, is then calculated by substituting the test ambient pressure p_y into the equation:

$$p_1 = 0{,}925 \times 100 = 92{,}5$$

If the measured fuel consumption at 838 kW is 238 g/(kW·h), then the fuel consumption adjusted to site ambient conditions can be determined using clause 11 of ISO 3046-1 : 1986, with the equation

$$b_x = \frac{b_y}{\beta_y}$$

where

b_x is the specific fuel consumption at site ambient conditions;

b_y is the specific fuel consumption at test ambient conditions;

$$\beta_y = \frac{k_y}{\alpha_y}$$

Substituting,

$$\beta_y = \frac{1{,}284}{1{,}320} = 0{,}973$$

Then the specific fuel consumption at the site conditions in grams per kilowatt hour will be

$$b_x = \frac{238}{0{,}973} = 245$$