TC 70

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Reciprocating internal combustion engines : Performance — Part II : Test methods

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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 3046/II was developed by Technical Committee ISO/TC 70, *Internal combustion engines*, and was circulated to the member bodies in October 1975.

It has been approved by the member bodies of the following countries :

Australia	India	Switzerland
Austria	Italy	Turkey
Brazil	Japan	United Kingdom
Bulgaria	Mexico	U.S.A.
Czechoslovakia	Netherlands	U.S.S.R.
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France	South Africa, Rep. of	
Germany	Sweden	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Belgium
Denmark

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Reciprocating internal combustion engines : Performance — Part II : Test methods

1 SCOPE

This International Standard 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 International Standard does not cover engines used to propel :

a) aircraft;

b) automobiles and trucks;

c) agricultural and industrial types of tractors;

d) road construction and earth-moving machines;

e) motorcycles.

3 REFERENCES

ISO 1204, *Reciprocating internal combustion engines — Designation of the direction of rotation.*

ISO 1205, *Reciprocating internal combustion engines — Designation of the cylinders.*

ISO 3046/I, *Reciprocating internal combustion engines : Performance — Part I : Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption.*

ISO 3046/III, *Reciprocating internal combustion engines : Performance — Part III : Common techniques of measurement.*[1)]

ISO 3046/IV, *Reciprocating internal combustion engines : Performance — Part IV : Speed governing.*[1)]

4 CATEGORIES OF TESTS (DEFINITIONS)

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

4.3 special tests : Tests additional to acceptance or type tests carried out to meet the requirements of inspecting and legislative authorities, Classification Societies or customers. Special tests shall be subject to agreement between the manufacturer and such authorities and/or the customer.

5 EXTENT OF TESTS

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

5.2 It is the responsibility of the manufacturer to define the extent of measurements and these 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 table 2.

TABLE 1 — **Measurement selection guide**

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

1) At present at the stage of draft.

5.3 For high volume production engines not all tested on load, an adequate inspection procedure may be used instead of a full acceptance test.

5.4 Dependent on the test categories and the extent of tests, five lists of recommended measurements and checks (A, B, C, D, E) are given in clause 8.

6 TEST CONDITIONS

6.1 Before an engine test, the manufacturer shall submit complete technical documentation concerning the engine type and application, when mutually agreed by the manufacturer and the customer.

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

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

6.4 Tests shall be carried out on the engine equipped with dependent auxiliaries, supplied with the engine and necessary for its operation.

6.5 Provided that the contractual requirements are fulfilled, test bed equipment may be used during the tests. Any variations in the performance of the test equipment shall be agreed between the manufacturer and the customer.

6.6 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 system or generator coupled to the engine.

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

6.8 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 mutually taken by the manufacturer and the customer.

6.9 The standard reference conditions and declarations of power, fuel and oil consumptions shall be as specified in ISO 3046/I.

6.10 Correction or adjustment of power output and specific fuel consumption

6.10.1 Where the test conditions differ significantly (see 6.10.3) from the standard reference conditions, or from site conditions, the test power output may be, if required, corrected by calculation. Alternatively, the engine may be tested at a substitute power and/or under test conditions altered artificially to simulate the site conditions.

6.10.2 This correction will be carried out to determine :

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

— the permissible maximum power under conditions different from the standard reference conditions to prevent the engine overloading.

6.10.3 Correction of power output and specific fuel consumption is carried out only if any of the engine operating conditions differs from the standard reference conditions by more than :

— ± 6 K from the absolute ambient temperature;

— ± 2 kPa[1] from the barometric pressure;

— ± 6 K from the absolute coolant temperature at the inlet of a charge air cooler.

6.10.4 Power and specific fuel consumption shall be determined using the fomulae in ISO 3046/I.

6.10.5 If in ISO 3046/I there is no suitable formula for adjustment of the power output and the specific fuel consumption, the method of adjustment shall be agreed in writing by the manufacturer and the customer.

6.10.6 If a turbocharged engine at the declared power output and under the standard reference conditions attains neither the turbocharger rotational frequency limits nor the gas temperature at the turbine inlet, the manufacturer may declare substitute reference ambient conditions for standard reference conditions as specified in ISO 3046/I.

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

1) 1 bar = 100 kPa

6.10.8 Engine tests may be carried out at any other (non-declared) power under ambient conditions created artificially to simulate site conditions. To simulate the site conditions the following methods may be used :

a) throttling of the engine (turbocharger) inlet with simultaneous depression at the outlet by an extraction device;

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 intercooler, the effect of increased ambient temperature can be easily simulated by throttling at the turbocharger inlet until the air temperature after the intercooler is the same as that on site. The throttle ratio can be determined using the figure (page 6).

NOTE – Examples illustrating how correction and simulation of ambient high temperature on site are applied when testing are given in the annex.

7 MEASUREMENT TECHNIQUES

For the methods to be used during acceptance and type tests for measuring engine parameters, symbols for parameters under measurement, units, etc., refer to ISO 3046/III.

8 TEST PROCEDURES

8.1 Acceptance tests

8.1.1 Acceptance tests comprise a specified sequence of power settings with measurement and calculation of the parameters given in lists A and B and the checks given in list C.

8.1.2 Measurements in list A normally shall be made according to the specified engine group number in table 2 for each operating condition wherever appropriate and where provision exists on the engine for doing so. The groups of 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 in the group chosen, this shall be stated by the manufacturer.

8.1.3 As a function of the calculated values based on test measurements obtained from list A, the manufacturer shall supply the following calculated values :

List B

B1 : brake power;

B2 : brake specific fuel consumption.

TABLE 2 – **List A – Test measurements**

No.	Parameter to be measured	Measurement groups Engine group number (see table 1)				
		1	2	3	4	5
A1	Barometric pressure, humidity and ambient temperature		X	X	X	X
A2	Engine rotational frequency or cycle frequency	X	X	X	X	X
A3	Engine torque and/or	X	X	X	X	X
A4	Fuel pump or governor or throttle control rod setting					
A5	Fuel consumption		X	X	X	X
A6	Lubricating oil pressure		X	X	X	X
A7	Temperature and pressure of exhaust gas leaving the engine		X	X	X	X
A8	Air pressure and temperature at engine or pressure charger inlet		X	X	X	X
A9	Gas temperature before turbocharger			X	X	X
A10	Boost pressure in the air manifold			X	X	X
A11	Turbocharger rotational frequency			X	X	X
A12	Coolant mean temperature in and out of cylinder block			X	X	X
A13	Lubricating oil temperature at the engine inlet and outlet			X	X	X
A14	Air pressure drop through the air cooler			X	X	X
A15	Boost pressure after each air cooler			X	X	X
A16	Charge air temperature after each air cooler			X	X	X
A17	Charge coolant inlet and outlet temperature			X	X	X
A18	Maximum cylinder pressure				X	X
A19	Gas pressure at turbocharger inlet			X	X	X
A20	Exhaust temperature of each cylinder				X	X
A21	Individual coolant circuit temperatures and pressures				X	X
A22	Lubricating oil pressure in individual circuits, e.g. turbo-charger, piston cooling, etc.				X	X
A23	Lubricating oil pressure before and after filters and coolers				X	X
A24	Secondary coolant and lubricating oil temperatures in and out of heat exchangers				X	X
A25	Fuel supply pressure and temperature				X	X
A26	Compression pressure					X
A27	Additional items may be included by agreement between manufacturer and customer	X	X	X	X	X

8.1.4 *Functional checks*

List C comprises functional checks which may be made additionally to engines in groups 2 to 5 in list A. The

selection from list C shall be made by agreement between the manufacturer and the customer.

List C

Functional checks will be carried out to demonstrate :

C1 : the correct functionning of the overspeed safety device;

C2 : the dynamic and steady state characteristics of the governing system in accordance with ISO 3046/IV;

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 function of all automatic pressure and temperature controls;

C5 : the ability of the starting system to perform in accordance with the contract;

C6 : vibration frequencies and amplitudes at prescribed rotational frequencies and loads when the engine is tested coupled to its contract driven machinery;

C7 : the function of the reversing mechanism, built-in reverse reduction gear and couplings;

C8 : the condition of one or more piston and cylinder assemblies and bearings chosen at random by inspection;

C9 : additional checks may be included by agreement between the manufacturer and the customer.

8.2 Type tests

8.2.1 A type test comprises a specified sequence of load/rotational frequency combinations, reversals and stops.

8.2.2 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 : engine heat balance;

D4 : dismantling and measuring of important parts subject to wear.

8.3 Special tests

Any special tests in list E which may be required by inspecting authorities, Classification Societies, by legislation or by the customer, shall be subject to agreement between the manufacturer and such authorities and/or the customer.

List E (Typical examples)

E1 : sound level;

E2 : exhaust emission characteristics;

E3 : tests in conjunction with contract driven machinery;

E4 : parallel running and other electrical tests of engine-driven generators;

E5 : emergency reversal of marine engines;

E6 : determination of minimum stable rotational frequency of marine engines;

E7 : changeover on dual fuel engines;

E8 : ability to carry out maintenance tasks within the time stated by the manufacturer;

E9 : ability to manoeuvre and provide a stated power when operating with prescribed malfunctions, for example with one or more turbochargers inoperative.

9 TEST REPORT

9.1 The manufacturer shall provide a test report.

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

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

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

a) date, place, nature of test and inspecting authority;

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

c) dependent auxiliaries, engine settings and proprietary equipment;

d) table of values measured during the test;

e) interpretation of certain measurements as required;

f) reference to this International Standard.

ANNEX

CORRECTION AND SIMULATION OF HIGH ON-SITE AMBIENT TEMPERATURE – EXAMPLES

A.1 EXAMPLE 1

A 4-stroke turbocharged engine with charge air intercooling will develop 640 kW (P_{ra}) under site conditions, where :

$p_{ra} = 70$ kPa
$T_{ra} = 330$ K
$T_{ca} = 300$ K
$\eta_m = 0{,}85$

What power should be developed under test conditions, where :

$p_x = 100$ kPa
$T_x = 300$ K
$T_{cx} = 280$ K

NOTE – See ISO 3046/I for explanation of the symbols.

Following the formulae from ISO 3046/I we can first adjust the engine power output developed under site conditions to the reference conditions :

– indicated power factor

$$k_r = \left(\frac{p_{ra}}{p_r}\right)^m \left(\frac{T_r}{T_{ra}}\right)^n \left(\frac{T_{cr}}{T_{ca}}\right)^q$$

$$= \left(\frac{70}{100}\right)^{0,7} \left(\frac{300}{330}\right)^{1,2} \left(\frac{300}{300}\right)^1 = 0{,}695$$

– power adjustment factor

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

$$= 0{,}695 - (0{,}7 \times 0{,}305 \times 0{,}18) = 0{,}657$$

– the engine power output $P_r = \frac{P_{ra}}{\alpha_r} = \frac{640}{0{,}657} = 974$ kW

The results thus attained may be adjusted to the test conditions :

$$k_x = \left(\frac{1{,}0}{1{,}0}\right)^{0,7} \left(\frac{300}{300}\right)^{1,2} \left(\frac{300}{280}\right)^1 = 1{,}071$$

$$\alpha_x = 1{,}071 + (0{,}7 \times 0{,}071 \times 0{,}18) = 1{,}08$$

$$P_x = 974 \times 1{,}08 \approx 1\,052 \text{ kW}$$

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 808 kW.

When defining factors k and α the tables and nomograms from ISO 3046/I may be used. In the above calculation, the nomogram given in annex L in ISO 3046/I may be used. Initially the engine output developed under site conditions will be adjusted to the standard reference conditions and then the results attained will be adjusted to test conditions.

A.2 EXAMPLE 2

The engine is required to be tested under conditions simulating site conditions (example 1), for example at a higher ambient temperature, $T_{ra} = 330$ K.

To simulate higher ambient temperature the method of throttling the air intake is used and the temperature after the cooler will be equal to that reached under site conditions. The temperature or coolant flow control at the charge air cooler inlet must be adjusted accordingly.

Ratio of throttling (decompression) for a temperature ratio $\frac{T_{ra}}{T_x} = \frac{330}{300} = 1{,}10$ and for an assumed pressure ratio $\frac{p_2}{p_x} = 2{,}5$:

$\frac{p_1}{p_x} = 0{,}925$, from the figure.

Thus power correction and adjustment factors become :

$$k_x = \left(\frac{p_x}{p_{ra}}\right)^m = \left(\frac{100}{70}\right)^{0,7} = 1{,}28$$

$$\alpha_x = 1{,}28 + (0{,}7 \times 0{,}28 \times 0{,}176) = 1{,}31$$

Therefore, when simulating site conditions using throttling at the air intake, the engine shall be tested at a power :

$$P_x = \alpha_x P_{ra} = 1{,}31 \times 640 = 828 \text{ kW}$$

If the measured fuel consumption at 828 kW is 238 g/kW·h, then the fuel consumption corrected to site conditions will be :

$$b_{ra} = \frac{b_x}{\beta_x} = 238\,\frac{1{,}31}{1{,}28} = 243 \text{ g/kW·h}$$

where $\beta_x = \frac{k_x}{\alpha_x}$ = fuel consumption adjustment factor.