INTERNATIONAL STANDARD

ISO 2288

Second edition
1989-12-01

Agricultural tractors and machines — Engine test code (bench test) — Net power

Tracteurs et machines agricoles — Code d'essai des moteurs (essai au banc) — Puissance nette

Reference number
ISO 2288 : 1989 (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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 2288 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*.

This second edition cancels and replaces the first edition (ISO 2288 : 1979), of which it constitutes a technical revision, incorporating Amendment 1 of 1983.

Annexes A, B, C and D of this International Standard are for information only.

NOTE — ISO 1585, the terminology of which is based on ISO 2710 : 1978, *Reciprocating internal combustion engines — Vocabulary,* is also the basis for the following parallel documents:

ISO 4106 : 1978, *Road vehicles — Motorcycles — Engine test code — Net power.*

ISO 4164 : 1978, *Road vehicles — Mopeds — Engine test code — Net power.*

ISO 9249 : 1989, *Earth-moving machinery — Engine test code — Net power* (to be published).

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

Agricultural tractors and machines — Engine test code (bench test) — Net power

1 Scope

This International Standard specifies a bench method for testing the categories of engines indicated below which are intended for use in agricultural tractors and machines and which may be fitted with a charging device using a mechanical supercharger or turbocharger:

a) spark-ignition engines;

b) compression-ignition (diesel) engines.

Engines given in a) and b) can be of the following types :

c) reciprocating internal combustion engines;

d) rotary piston internal combustion engines.

In particular, this International Standard allows curves of net power and specific fuel consumption at full load to be plotted as functions of engine speed.

NOTE — This International Standard is in conformity with ISO 1585; it relates to tests on an engine capable of being fitted into several types of agricultural tractors and machines.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 789-1 : 1981, *Agricultural tractors — Test procedures — Part 1 : Power tests.*

ISO 1585 : 1982, *Road vehicles — Engine test code — Net power.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 net power : Power obtained on a test bed at the crankshaft or equivalent, at the engine speed specified by the manufacturer, the engine being equipped with the standard production auxiliaries necessary to its operation for the particular application.

3.2 auxiliaries : Equipment and devices listed in table 1.

3.3 standard production equipment : Any equipment normally provided or recommended by the manufacturer for the particular engine application.

4 Accuracy of measurements

4.1 Torque

The dynamometer torque-measuring system shall give an accuracy within ± 1 % in the range of scale values required for the test.

4.2 Engine rotational frequency

Engine rotational frequency shall be measured preferably with a revolution counter and an automatically synchronized chronometer (or counter timer). The accuracy of the measured value shall be ± 0,5 %.

4.3 Fuel consumption

Accuracy of fuel consumption measurements shall be ± 1 % overall for the apparatus used.

4.4 Engine inlet air temperature

The accuracy of this temperature measurement shall be ± 2 K.

4.5 Barometric pressure

Barometric pressure shall be measured to ± 70 Pa (± 0,7 mbar*)).

4.6 Pressure in exhaust extraction duct

Subject to footnote 1) to table 1, this pressure shall be measured to ± 25 Pa (± 0,25 mbar*)).

Table 1 — Installation of auxiliaries during test

No.	Auxiliaries	Fitted for net power test
1	Intake system Intake manifold Air filter Intake silencer and duct work Crankcase emission control system Speed-limiting device	Yes, standard production equipment
2	Induction heating device of intake manifold	Yes, standard production equipment. If possible, to be set in the most favourable condition
3	Exhaust system Exhaust purifier Manifold Connecting pipes[1)] Silencer[1)] Tail pipe[1)] Exhaust brake[2)]	Yes, standard production equipment
4	Fuel supply pump[3)]	Yes, standard production equipment
5	Carburettor	Yes, standard production equipment
6	Fuel injection equipment (petrol and diesel) Prefilter Filter Pump High pressure pipe Injector Air intake valve (if fitted)[4)] Governor (if fitted)	Yes, standard production equipment

1) If it is impracticable to fit the standard exhaust system, a system of equivalent restriction may be fitted for the test, provided that this is acceptable to the manufacturer.

In the test laboratory, the exhaust extraction system at the point where the test bed exhaust system is connected shall not, with the engine in operation, create a pressure differing from the atmospheric pressure by more than ± 740 Pa (± 7,4 mbar), at the exhaust extraction duct, unless the manufacturer has accepted a higher back-pressure prior to the test.

2) If an exhaust brake is incorporated in the engine, the throttle valve may be removed or fixed in the fully open position.

3) The fuel feed pressure shall be adjusted, if necessary, to reproduce the inlet pump pressure consistent with the particular engine application (particularly where a fuel return system is used).

4) The air intake valve is the control valve for the pneumatic governor of the injection pump.

*) 1 bar = 10^5 Pa

Table 1 — (*concluded*)

No.	Auxiliaries	Fitted for net power test
7	Liquid cooling equipment	
	Radiator Fan[6), 7)] Fan cowl Water pump Thermostat[8)]	Yes[5)], standard production equipment
8	Air cooling	
	Cowl Fan or blower[6), 7)]	Yes, standard production equipment
	Auxiliary test bed fan	Yes, if necessary
	Temperature regulating device	Yes, standard production equipment
9	Electrical equipment[9)]	Yes, standard production equipment
10	Pressure-charging equipment (if fitted)	
	Compressor-driven either directly or indirectly by the engine (supercharger), and/or by the exhaust gases (turbocharger) Intercooler[10)] Coolant pump or fan (engine-driven) Coolant flow control device (if fitted)	Yes, standard production equipment
	Auxiliary test bed fan	Yes, if necessary
11	Anti-pollution devices	Yes, standard production equipment

5) The radiator, fan, fan cowl, water pump and thermostat shall be located on the test bed in the same relative positions as those they will occupy on the vehicle. The cooling liquid circulation shall be operated by the engine water pump only.

Cooling may be produced either by the engine radiator or by an external circuit, provided that the pressure loss of this circuit remains substantially the same as that of the engine cooling system. The radiator shutter, if incorporated, shall be in the open position.

6) Where a disconnectable fan or blower is incorporated, the net power shall be determined firstly with the fan or blower disconnected, then with it connected.

7) Where a fixed fan, electrically or mechanically operated, cannot be fitted on the test bed, the power absorbed by the fan should be determined at the same engine speeds as those used for the measurement of the engine power. This power shall be deducted from the corrected power to obtain the net power.

8) The thermostat may be fixed in the fully open position.

9) Minimum power of the generator : the power of the generator shall be limited to that necessary for the operation of accessories which are indispensable for the operation of the engine. If the connection of a battery is necessary, a fully charged battery in good order shall be used.

10) The temperature of the air at the inlet manifold shall be that specified by the engine manufacturer, if such a specification is given.

5 Tests

5.1 Auxiliaries

The engine auxiliaries to be considered are those necessary for the use of the engine in an agricultural tractor or machine.

During the test, the auxiliaries specified below shall be installed on the bench, as far as possible, in the same position as in the intended application.

5.1.1 Auxiliaries to be fitted

The auxiliaries which shall be fitted during the test are listed in table 1. In addition, the all-speed governor of the fuel supply equipment shall be fitted.

5.1.2 Auxiliaries to be removed

All the auxiliaries except those detailed in 5.1.1 shall be removed for the test, where possible, i.e. all except the auxiliaries necessary for the correct operation of the vehicle and usually fitted to the engine. The following non-exhaustive list is given as an example :

— air compressor for brakes;

— power steering pump;

— hydraulic lift pump;

— air-conditioning system.

Where auxiliaries cannot be removed, the power absorbed by them in the unloaded condition shall be determined (if this cannot be determined, the manufacturer's estimate may be used) and added to the measured engine power.

5.1.3 Compression-ignition engine starting auxiliaries

For auxiliaries used in the starting of compression-ignition engines, the two following cases shall be considered :

a) Electrical starting. The generator is fitted and supplies, where necessary, the auxiliaries indispensable to the operation of the engine.

b) Starting other than electrical. If there are any electrically operated accessories indispensable to the operation of the engine, the generator is fitted to supply these accessories. Otherwise, it is removed.

In either case, the system for producing and accumulating the energy necessary for starting is fitted and operates in the unloaded condition.

5.2 Setting conditions

The setting conditions for the tests to determine net power are indicated in table 2.

Table 2 — Setting conditions

1	Setting of carburettor(s)	In accordance with the manufacturer's production specifications and used without further alteration for the particular application
2	Setting of injection pump delivery system	
3	Ignition or injection timing (timing curve)	
4	Governor setting	

5.3 Test conditions

5.3.1 The test shall consist of a run at full throttle for spark-ignition engines and at full load fuel pump setting for compression-ignition engines, the engine being equipped as specified in table 1.

5.3.2 Performance data shall be obtained under stabilized normal operating conditions, with an adequate fresh air supply to the engine. The engines shall have been run-in in accordance with the manufacturer's recommendations. Combustion chambers of spark-ignition engines may contain deposits, but in limited quantity. Test conditions such as inlet air temperature shall be selected as near to reference conditions (see 6.2) as possible in order to minimize the magnitude of the correction factor.

5.3.3 The temperature of the inlet air to the engine (ambient air) shall be measured not more than 0,15 m upstream of the air intake duct. The thermometer or thermocouple shall be shielded from radiant heat and located directly in the air stream. It shall also be shielded from fuel spray-back. A sufficient number of locations shall be used to give a representative average inlet temperature.

5.3.4 No data shall be taken until torque, rotational frequency and temperature have been maintained substantially constant for at least 1 min.

5.3.5 The engine rotational frequency during a run or reading shall not deviate from the selected rotational frequency by more than ± 1 % or ± 10 r/min, whichever is the greater.

5.3.6 Observed brake load, fuel consumption and inlet air temperature data shall be recorded simultaneously and shall in each case be the average of two stabilized sustained readings which do not vary by more than 2 % for brake load and fuel consumption.

5.3.7 A measurement time of not less than 30 s shall be used when measuring speed and fuel consumption with an automatically synchronized counter time combination; for hand operation, the measurement time shall be not less than 60 s.

5.3.8 The temperature of the coolant at the outlet from the engine shall be kept within ± 5 K (± 5 °C) of the upper thermostatically controlled temperature specified by the manufacturer. If no temperature is specified by the manufacturer, the temperature shall be 353 K ± 5 K (80 °C ± 5 °C).

5.3.9 For spark-ignition engines, the fuel temperature shall be measured at the inlet to the carburettor or fuel injection system, and maintained within ± 5 K (± 5 °C) of the temperature specified by the engine manufacturer, with a minimum of 293 K (20 °C).

If this temperature is not specified by the manufacturer, it shall be 298 K ± 5 K (25 °C ± 5 °C).

For compression-ignition engines, the fuel temperature shall be measured at the inlet to the fuel injection system, and maintained within ± 5 K (± 5 °C) of the temperature specified by the engine manufacturer, with a minimum of 303 K (30 °C).

If this temperature is not specified by the manufacturer, it shall be 313 K ± 3 K (40 °C ± 3 °C).

5.3.10 The lubricant temperature shall be measured at the inlet of the oil gallery or at the outlet from the oil cooler, if fitted, unless a different measuring location is specified by the manufacturer. The temperature shall be maintained within the limits established by the manufacturer.

5.3.11 The exhaust temperature shall be measured at a point in the exhaust pipe(s) adjacent to the outlet flange(s) of the exhaust manifold(s). This temperature shall be maintained within the limits established by the engine manufacturer.

5.3.12 The fuel used shall conform to the specifications published by the manufacturer of the engine under test.

For compression-ignition engines, the fuel shall be one supplied and delivered by the refinery to the customer without any smoke-suppressant additives. In cases of dispute, tests shall be made with the CEC[1] reference fuel CEC RF-03-A-84 (see annex B). For spark-ignition engines, in cases of dispute, tests shall be carried out using CEC reference fuel CEC RF-01-A-80 or CEC RF-08-A-85 (see annex A or C).

5.4 Test procedure

Record data at a sufficient number of operating rotational frequencies to define completely the power curve between the lowest and the highest engine rotational frequencies recommended by the manufacturer. For part-load performance measurement, see ISO 789-1.

5.5 Data to be recorded

Data to be recorded are those indicated in clause 8.

6 Correction factors

NOTE — The tests may be carried out in air-conditioned test rooms where atmospheric conditions may be controlled.

6.1 Definition of factor α

Factor by which the observed power shall be multiplied to determine the corrected engine power, P_o, under the reference atmospheric conditions specified in 6.2 :

$$P_o = \alpha P$$

where

α is the correction factor (α_a or α_d);

P is the measured (observed) power.

6.2 Atmospheric conditions

6.2.1 Reference atmospheric conditions

The reference atmospheric conditions shall be as given in 6.2.1.1 and 6.2.1.2.

6.2.1.1 Temperature

The reference temperature, T_o, is 298 K (25 °C), or 300 K (27 °C) for severe atmospheric conditions.

6.2.1.2 Dry pressure

The reference dry pressure, P_{so}, is 99 kPa.[2]

6.2.2 Test atmospheric conditions

The test atmospheric conditions shall be within the values given in 6.2.2.1 and 6.2.2.2 during the test.

6.2.2.1 Temperature, T

For spark-ignition engines

$$288 \text{ K } (15 \text{ °C}) \leqslant T \leqslant 308 \text{ K } (35 \text{ °C})$$

For compression-ignition engines

$$283 \text{ K } (10 \text{ °C}) \leqslant T \leqslant 313 \text{ K } (40 \text{ °C})$$

6.2.2.2 Dry pressure, p_s

For all engines

$$80 \text{ kPa} \leqslant p_s \leqslant 110 \text{ kPa}$$

6.3 Limitations in use of correction formulae

The correction formulae given in 6.4.1 and 6.4.2 are only applicable where the correction factors, α_a and α_d, are within the limits indicated in 6.3.1 and 6.3.2.

6.3.1 Spark-ignition engines (naturally aspirated and pressure-charged)

$$0{,}93 \leqslant \alpha_a \leqslant 1{,}07$$

6.3.2 Compression-ignition engines

$$0{,}9 \leqslant \alpha_d \leqslant 1{,}1$$

6.3.3 Exceeding limits

If the limits given in 6.3.1 and 6.3.2 are exceeded, the corrected value obtained shall be given, and the test conditions (temperature and pressure) precisely stated in the test report.

1) Co-ordinating European Council for the Development of Performance Tests for Lubricants and Engine Fuels. These fuels can be obtained from the Council at
61 New Cavendish Street
London W1M 8AR
United Kingdom
This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

2) The dry pressure is based on a total pressure of 100 kPa and a vapour pressure of 1 kPa.

6.4 Determination of correction factors

6.4.1 Spark-ignition engines (naturally aspirated and pressure-charged)

The correction factor, α_a, for spark-ignition engines (carburetor or injection) shall be as calculated from the formula

$$\alpha_a = \left(\frac{99}{p_s}\right)^{1,2} \left(\frac{T}{298}\right)^{0,6}$$

where

T is the absolute temperature, in kelvins (K), at the air inlet to the engine;

p_s is the dry atmospheric pressure, in kilopascals, i.e. the total barometric pressure minus the water vapour pressure.

In the case of engines fitted with automatic air temperature control, if the device is fully closed at full load at 298 K (25 °C) (no heated air added to the intake air) the test shall be carried out with the device fully closed and the normal correction factor applied. If the device is still operating at 299 K (26 °C) then the test is made with the device operating normally and the exponent of the temperature term in the correction factor shall be taken as zero (no temperature correction).

6.4.2 Compression-ignition engines

6.4.2.1 Correction factor, α_d

The correction factor, α_d, for compression-ignition engines at constant fuel rate shall be as calculated from the formula:

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

where

f_a is the atmospheric factor (see 6.4.2.2);

f_m is the engine factor, i.e. the characteristic parameter for each type of engine and adjustment (see 6.4.2.3).

6.4.2.2 Atmospheric factor, f_a

The atmospheric factor, f_a, which indicates the effect of environmental conditions (pressure, temperature and humidity) on the air drawn in by the engine shall be as calculated from the formula in either a) or b):

a) naturally aspirated and mechanically pressure-charged engines:

$$f_a = \left(\frac{99}{p_s}\right) \left(\frac{T}{298}\right)^{0,7}$$

b) turbocharged engines, with or without cooling of charge air:[1)]

$$f_a = \left(\frac{99}{p_s}\right)^{0,7} \left(\frac{T}{298}\right)^{1,5}$$

where T and P_s are as defined in 6.4.1.

6.4.2.3 Engine factor, f_m

Within the limits established for α_d in 6.3.2, the engine factor, f_m, is a function of the corrected fuel flow, q_c, and shall be as calculated from the formula:

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

where

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

in which

q is the fuel flow, in milligrams per cycle per litre of engine swept volume per cycle [mg/(l·cycle)];

r is the pressure ratio of the compressor outlet to the compressor inlet ($r = 1$ for naturally aspirated engines).

The formula for the engine factor, f_m, is only valid for a q_c value between 40 mg/(l·cycle) and 65 mg/(l·cycle). For values less than 40 mg/(l·cycle), a value of 0,3 shall be taken for f_m, whilst for values greater than 65 mg/(l·cycle), a value of 1,2 shall be taken for f_m (see figure 1).

7 Measurement of smoke value

The measurement of smoke value is not currently included in the test code.

The measurement is optional.

1) The correction factor should be regarded as provisional. Studies are in progress to establish a more accurate formula.

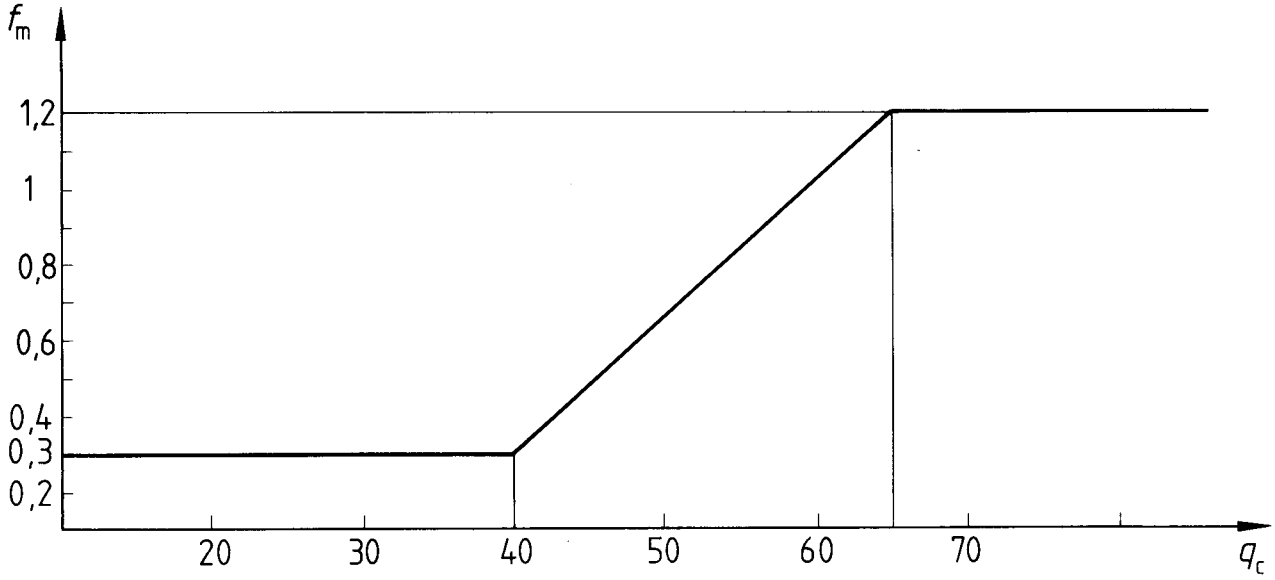

Figure 1 — Engine factor, f_m, as a function of corrected fuel flow, q_c

8 Test report

(State "none" where inapplicable, or delete.)

8.1 Engine data

8.1.1 Reciprocating engines

Make : ..... Type : ..... Serial No. (in the type series) : .....

Bore : ..... Stroke : ..... Swept volume of one cylinder : .....

Number of cylinders : ..... Arrangement of cylinders : .....

Total swept volume of the cylinders : ..... Ignition : spark/compression[1)]
firing or injection order : .....

Compression ratio : ..... Cycle : 2/4[1)] stroke

Pressure-charging device — Make : ..... Type : ..... Serial No. : .....

8.1.2 Rotary trochoidal engines

Make : ..... Type : ..... Serial No. (in the type series) : .....

Epitrochoidal/hypotrochoidal[1)]

Envelope : internal/external[1)]

Number of gas-tight chambers between the rotor and the stator,
i.e. number of peripheral sealing devices per rotor or stator : .....

Eccentricity : ..... Generating radius : .....

1) Delete where inapplicable.

Operating width : ..... Swept volume of one gas-tight chamber : .....

Number of rotors : ..... Ignition : spark/compression[1)]
firing or injection order : .....

Compression ratio : ..... Cycle : 2/4[1)] stroke

Pressure-charging device — Make : ..... Type : ..... Serial No. : .....

8.2 Fuel supply

Pump — Make : ..... Type : ..... Serial No. : .....

Prefilter : yes/no[1)] Filter : yes/no[1)]

8.3 Carburettor

Make : ..... Type : ..... Serial No. : .....

Number : ..... Detailed specifications : .....

8.4 Injection pumps or devices

Make : ..... Type : ..... Serial No. : .....

Static timing : ..... Advance device : .....

Manufacturer's code : .....

8.5 Injection nozzles and nozzle holders

Make : ..... Type : ..... Serial No. : .....

Setting pressure : ..... Injection high pressure pipes { lengths : .....
inside diameter : .....

8.6 Governor

Make : ..... Type : ..... Serial No. : .....

Cutting-in rotational frequency under load : ..... r/min

Maximum no-load rotational frequency : ..... r/min

8.7 Ignition distributor

Make : ..... Type : ..... Serial No. : .....

Static timing : ..... Advance device : .....

Timing at ..... r/min : ..... (as specified by the manufacturer)

Maximum range of advance device : .....

Distributor contact breaker gap : .....

1) Delete where inapplicable.

8.8 Spark-plugs

Make : ..... Type or No. : .....

Number per cylinder : ..... Electrode gap : .....

8.9 Ignition coils

Make : ..... Type : ..... Serial No. : .....

Number : .....

8.10 Glow-plugs

Make : ..... Type or No. : ..... Number : .....

8.11 Interference suppressor

Make : ..... Type : ..... Serial No. : .....

8.12 Intake system

Intake manifold : ..... Description : .....

Air filter — Make : ..... Type : ..... Serial No. : .....

Intake silencer — Make : ..... Type : ..... Serial No. : .....

Inlet maximum depression at full flow recommended by the manufacturer : ..... kPa/mbar[1)]

8.13 Valve gear

Type : ..... Brief description : .....

Valve timing : ..... Tappet clearances (hot/cold[1)]) : .....

8.14 Crankcase emission control system

Brief description : .....

Make : ..... Type : ..... Serial No. : .....

8.15 Induction heating device

Type : ..... Brief description : .....

8.16 Exhaust system

Pipes and other components : standard/not standard[1)]

Brief description if not standard : .....

Exhaust brake — Make : ..... Type : ..... Serial No. : .....

Silencer — Make : ..... Type : ..... Serial No. : .....

1) Delete where inapplicable.