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Agricultural tractors and machines — Engine test code — Net power

*Tracteurs et machines agricoles — Code d'essai des moteurs —
Puissance nette*



Foreword

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International Standard ISO 2288 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 2, *Common tests*.

This third edition cancels and replaces the second edition (ISO 2288:1989), which has been technically revised.

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Agricultural tractors and machines — Engine test code — Net power

1 Scope

This International Standard specifies a method for testing internal combustion engines intended for propulsion of agricultural tractors and machines. It applies to evaluation of performance with a view, in particular, to presenting curves of power and specific fuel consumption at full load as a function of engine speed. The engines may be naturally aspirated or pressure-charged.

It applies to net power assessment.

This International Standard concerns internal combustion engines used in agricultural tractors and machines and included in one of the following categories:

- reciprocating internal combustion engines (spark-ignition or compression-ignition) but excluding free piston engines;
- rotary piston engines.

These engines may be naturally aspirated or pressure-charged, either using a mechanical pressurecharger or turbocharger.

NOTE - This International Standard provides engine power correction factors in conformity with ISO 1585:1992.

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 listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 789-1:1990, *Agricultural tractors - Test Procedures - Part 1: Power tests for power take off.*

ISO 1585:1992, *Road vehicles - Engine test code - Net power.*

ISO 2710:1978, *Reciprocating internal combustion engines - Vocabulary.*

ISO 3104:1994, *Petroleum products - Transparent and opaque liquids - Determination of kinematic viscosity and calculation of dynamic viscosity.*

ISO 3173:1974, *Road vehicles - Apparatus for measurement of the opacity of exhaust gas from diesel engines operating under steady state conditions.*

ISO 3675:1993, *Crude petroleum and liquid petroleum products - Laboratory determination of density or relative density - Hydrometer method.*

ISO 5163:1990, *Motor and aviation-type fuels - Determination of knock characteristics - Motor method.*

ISO 5164:1990, *Motor fuels - Determination of knock characteristics - Research method.*

ISO 5165:1992, *Diesel fuels - Determination of ignition quality - Cetane method.*

ISO 7876-1:1990, *Fuel injection equipment - Vocabulary - Part 1: Fuel injection pumps*

ISO 7967-1:1987, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 1: Structure and external covers.*

ISO 7967-2:1987, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 2: Main running gear.*

ISO 7967-3:1987, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 3: Valves, camshaft drive and actuating mechanisms.*

ISO 7967-4:1988, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 4: Pressure charging and air/exhaust gas ducting systems.*

ISO 7967-5:1992, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 5: Cooling systems.*

ISO 7967-8:1994, *Reciprocating internal combustion engines - Vocabulary of components and systems - Part 8: Starting systems.*

ASTM D 240-87, *Standard test method for heat of combustion of liquid hydrocarbon fuels by bomb calorimeter.*

ASTM D 3338-88, *Standard test method for estimation of heat of combustion of aviation fuels.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 2710, ISO 7876-1, ISO 7967-1, ISO 7967-2, ISO 7967-3, ISO 7967-4, ISO 7967-5 and ISO 7967-8, and the following definitions apply.

3.1 net power

power obtained on a test bed at the end of the crankshaft or its equivalent at the corresponding engine speed with the equipment and auxiliaries listed in table 1.

NOTE - If the power measurement can only be carried out with a mounted gear-box, the losses in the gear-box should be added to the measured power to give the engine power.

3.2 standard production equipment

any equipment provided by the manufacturer for a particular engine application.

4 Accuracy of measuring equipment instruments

4.1 Torque

The dynamometer torque-measuring system shall have an accuracy within $\pm 1\%$ in the range of scale values required for the test.

4.2 Engine speed (rotational frequency)

The engine speed (rotational frequency) measuring system shall have an accuracy of $\pm 0,5\%$.

4.3 Fuel flow

The fuel flow measuring system shall have an accuracy of $\pm 1\%$.

4.4 Fuel temperature

The fuel temperature measuring system shall have an accuracy of $\pm 2\text{ K}$.

4.5 Air temperature

The air temperature measuring system shall have an accuracy of $\pm 2\text{ K}$.

4.6 Barometric pressure

The barometric pressure measuring system shall have an accuracy of $\pm 100\text{ Pa}$.

NOTE - $1\text{ Pa} = 1\text{ N/m}^2$

4.7 Back pressure in exhaust system

The system used to measure the back pressure in the exhaust system shall have an accuracy of $\pm 200\text{ Pa}$. The measurement shall be made subject to footnote 1b) of table 1.

4.8 Depression in inlet system

Subject to footnote 1a of table 1, this pressure shall be measured to $\pm 50\text{ Pa}$.

4.9 Absolute pressure in inlet duct

The system used to measure the absolute pressure in the inlet duct shall have an accuracy of $\pm 2\%$ of the measured pressure.

Table 1 - Equipment and auxiliaries to be installed for the test to determine net engine power

No.	Equipment & auxiliaries	Fitted for engine net power test
1	Inlet system Inlet manifold Crankcase emission control system Control devices for dual induction inlet manifold system Air flow meter ^{1a)} , Air inlet ductwork ^{1a)} , Air filter ^{1a)} , Inlet silencer ^{1a)} , Speed limiting device ^{1a)}	Yes, standard production equipment
2	Induction heating device of inlet manifold	Yes, standard production equipment if possible to be set in the most favorable position.
3	Exhaust system Exhaust purifier Exhaust manifold Pressure-charging devices Connecting pipes ^{1b)} , Silencer ^{1b)} , Tail pipe ^{1b)} , Exhaust brake ²	Yes, standard production equipment
4	Fuel supply pump ³⁾	Yes, standard production equipment
5	Carburation equipment Carburettor, Electronic control system, air-flow, etc. (if fitted), Equipment for gaseous fuel engines, Pressure reducer, Evaporator, Mixer	Yes, standard production equipment
6	Fuel injection equipment (Spark-ignition and compression ignition (diesel)) Prefilter, Filter, Pump, High-pressure pipe, Injector, Air inlet valve (if fitted) ⁴⁾ , Electronic control system, etc. (if fitted), Governor control system: automatic full-load stop for the control depending on atmospheric conditions	Yes, standard production equipment
7	Liquid cooling equipment Radiator, Fan ^{5), 6)} , Fan cowl, Water pump, Thermostat ⁷⁾	Yes, standard production equipment
8	Air cooling Cowl, Fan or blower ^{5), 6)} , Temperature regulating device	Yes, standard production equipment
9	Electrical or electronic ignition equipment Generator ⁸⁾ , Spark distribution system, Coil or coils, Wiring, Spark-plugs, Electronic control system including knock sensor/ spark-retard system ¹¹⁾	Yes, standard production equipment
10	Pressure-charging equipment (if fitted) Compressor driven either directly by the engine, and/or by the exhaust gases, Boost control ¹²⁾ , Charge-air-cooler ^{5), 6), 9)} , Coolant pump or fan (engine-driven), Coolant flow control devices (if fitted)	Yes, standard production equipment
11	Auxiliary test bed fan	Yes, if necessary
12	Anti-pollution devices ¹⁰⁾	Yes, standard production equipment

Table 1 - (concluded)

- 1a) Except in the case where there is a risk of the system having a noticeable influence upon engine power, an equivalent system may be used. In this case, a check should be made to ascertain that inlet depression does not differ by more than 100 Pa from the limit specified by the manufacturer for a clean air filter.
- 1b) Except in the case where there is a risk of the system having a noticeable influence upon engine power, an equivalent system may be used. In this case, a check should be made to ascertain that the back-pressure in the engine exhaust system does not differ by more than 1,000 Pa from the upper limit specified by the manufacturer.
- 2) If an exhaust brake is incorporated in the engine, the throttle valve shall be fixed fully open.
- 3) The fuel feed pressure may be adjusted, if necessary, to reproduce the inlet pump pressure conditions consistent with the particular engine application (particularly where a "fuel return" system, e.g. to tank or filter, is used).
- 4) The air inlet valve is the control valve for the pneumatic governor of the injection pump. The governor of the fuel injection equipment may contain other devices which may affect the amount of fuel injected.
- 5) The radiator, fan, fan cowl, water pump and thermostat shall be located on the test bed in the same relative positions that they will occupy on the machine. The cooling liquid circulation shall be operated by the engine water pump only.
- Cooling of the liquid may be produced either by the engine radiator or by an external circuit, provided that the pressure loss of this circuit and the pressure at the pump inlet remains substantially the same as those of the engine cooling system. The radiator shutter, if incorporated, shall be in the open position.
- Where the fan, radiator and cowl system cannot conveniently be fitted to the engine, the power absorbed by the fan when separately mounted in its correct position in relation to the radiator and cowl (if used), shall be determined at the speeds corresponding to the engine speeds used for measurement of the engine power either by calculation from standard characteristics or by practical tests. This power corrected to the standard atmospheric conditions defined in 6.2 shall be deducted from the corrected power.
- 6) Where a disconnectable or progressive fan or blower is incorporated, the test shall be made with the disconnectable fan or blower disconnected or with the progressive fan running as maximum slip.
- 7) The thermostat may be fixed in the fully open position.
- 8) 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 engine operation. If the connection of a battery is necessary, a fully charged battery in good order shall be used.
- 9) Charge-air-cooled engines shall be tested complete with charge-air-cooling whether liquid- or air-cooled, but, if the engine manufacturer prefers, a test bed system may replace the air-cooled cooler. In either case the measurement of power at each speed shall be made with the pressure drop and temperature drop of the engine air across the charge air cooler in the test bed the same as those specified by the manufacturer for the system on the complete machine.
- 10) They may include for example exhaust gas recirculation (EGR) system, catalytic converter, thermal reactor, secondary air supply system and fuel evaporation protecting system.
- 11) The spark advance shall be representative of in-use conditions established with the minimum octane fuel recommended by the manufacturer.
- 12) For engines equipped with variable boost as a function of charge or inlet air temperature, octane rating and/or engine speed, the boost pressure shall be representative of in-machine conditions established with the minimum octane fuel as recommended by the manufacturer.

5 Tests

5.1 Auxiliaries

5.1.1 Auxiliaries to be fitted

During the test, auxiliaries necessary to make the engine acceptable for service in the intended application (as listed in table 1) shall be installed on the test bed as far as possible in the same position as in the intended application.

5.1.2 Auxiliaries to be removed

Certain machine accessories necessary only for operation of the machine, and which may be mounted on the engine, shall be removed for the test. The following non-exhaustive list is given as an example:

- machine hydraulic system(s) pumps;
- machine control system(s) hydraulic system pumps;
- air compressor for machine systems;
- air-conditioning system compressor.

Where accessories cannot be removed, the power absorbed by them in the unloaded condition may be determined and added to the measured engine power.

5.1.3 Compression-ignition engine starting auxiliaries

For auxiliaries used to start 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 test 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 alternation for the particular application.
2	Setting of injection pump delivery system	
3	Ignition or injection timing (timing curve)	
4	Governor setting	
5	Anti-pollution devices	
6	Boost control	

5.3 Test conditions

5.3.1 The net power test shall consist of a run at full throttle for spark-ignition engines and at fixed full load fuel injection 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 operating conditions with an adequate fresh air supply to the engine.

Engines shall have been run-in in accordance with the manufacturer's recommendations. Combustion chambers 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 shall be measured within the inlet ductwork. The inlet depression measurement shall be made at the same point.

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 The inlet depression shall be measured downstream of the entry ducts, air filter, inlet silencer, speed-limiting device (if they are fitted) or their equivalents.

5.3.5 The absolute pressure at the entry to the engine downstream of the compressor and heat exchanger, if they are fitted, shall be measured in the inlet manifold and at any other point where pressure has to be measured to calculate correction factors.

5.3.6 The exhaust back pressure shall be measured at a point at least three pipe diameters from the outlet flanges(s) of the exhaust manifold(s) and downstream of the

turbocharger(s), if fitted. The location shall be specified.

5.3.7 No data shall be taken until torque, engine speed and temperature have been maintained substantially constant as specified by the manufacturer.

5.3.8 The engine speed during a run or reading shall not deviate from the selected speed by more than $\pm 1\%$ or $\pm 10 \text{ min}^{-1}$, whichever is greater.

5.3.9 Observed brake load, fuel flow and inlet air temperature data shall be taken simultaneously and shall, in each case, be the average of at least two stabilized consecutive readings which do not vary more than 2% for the brake load and fuel consumption. The second reading shall be determined without any adjustment of the engine, approximately 1 min after the first.

5.3.10 The temperature of the coolant at the outlet from the engine shall be kept within $\pm 5 \text{ K}$ of the upper thermostatically controlled temperature specified by the manufacturer. If no temperature is specified by the manufacturer, the temperature shall be $353 \text{ K} \pm 5 \text{ K}$.

For air-cooled engines, the temperature at a point indicated by the manufacturer shall be kept within -20^0 K of the maximum value specified by the manufacturer for the reference conditions.

5.3.11 Fuel temperatures shall be as follows.

a) For spark-ignition engines, the fuel temperature shall be measured as near as possible to the inlet of the or assembly of fuel injectors. Fuel temperature shall be maintained within $\pm 5 \text{ K}$ of the temperature specified by the manufacturer. However, the minimum test fuel temperature allowed shall be the ambient air temperature. If the test fuel temperature is not specified by the manufacturer, it shall be $298 \text{ K} \pm 5 \text{ K}$.

b) For compression-ignition engines, the fuel temperature shall be measured at the inlet to the fuel-injection pump. At the manufacturer's request the fuel temperature measurement can be made at another point in the pump representative of the engine operating condition. Fuel temperature shall be maintained within $\pm 3 \text{ K}$ of the temperature specified by the manufacturer. In all cases, the minimum allowable fuel temperature at the pump entrance is 303 K . If the test fuel temperature is not specified by the manufacturer, it shall be $313 \text{ K} \pm 3 \text{ K}$.

5.3.12 The lubricant temperature shall be measured at either the oil gallery inlet, the oil cooler outlet, if fitted, or as is specified by the manufacturer. The temperature shall be maintained within the limits specified by the manufacturer.

5.3.13 An auxiliary regulation system may be used if necessary to maintain temperatures within limits specified in 5.3.10, 5.3.11 and 5.3.12.

5.3.14 The selection of fuel for the net power test shall be agreed by the parties involved and the fuel shall be selected in accordance with table 3.

Table 3 -Test fuels

Test purpose	Involved parties	Fuel selection
Type approval (certification)	1. Certification body 2. Manufacturer or supplier	- Reference fuel, if one is defined - Commercial fuel if no reference fuel is defined
Acceptance test	1. Manufacturer or supplier 2. Customer or inspector	- Commercial fuel as specified by the manufacturer

5.4 Test Procedure

Measurements shall be taken at a sufficient number of engine speeds to define the power and torque curve completely between the lowest and the highest engine speeds recommended by the manufacturer. The range of speeds shall include the speed at which the engine produces its maximum power and torque. For part-load performance measurements, see ISO 789 Part 1.

5.5 Data to be recorded

Data to be recorded shall be those indicated in clause 8.

6 Correction factors

6.1 Definition of factor α for power correction

This is the factor by which the observed power shall be multiplied to determine the engine power at the reference atmospheric conditions specified in 6.2. The corrected power (i.e. power at reference conditions), P_{ref} is given by

$$P_{\text{ref}} = \alpha P_y$$

where

α is the correction factor (α_a being the correction factor for spark-ignition engines and α_c the correction factor for compression-ignition engines);

P_y is the measured (observed) power.

6.2 Atmospheric conditions

6.2.1 Reference atmospheric conditions

For the purpose of determining the power and fuel consumption of engines, the standard reference conditions given in 6.2.1.1 to 6.2.1.3 shall be used.

6.2.1.1 Temperature

The reference temperature, T_{ref} , is 298 K.

6.2.1.2 Dry pressure

The total barometric pressure, p_{ref} , is 100 kPa.

The reference dry barometric pressure, $p_{d,ref}$, is 99 kPa.

NOTE - Relative humidity of 30 % at a temperature of 298 K corresponds to a water vapor pressure of 1 kPa. Hence the corresponding dry barometric pressure is 99 kPa.

6.2.1.3 Relative humidity

The reference relative humidity, ϕ_{ref} , is 30 %.

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

$$288 \text{ K} \leq T \leq 308 \text{ K}$$

For compression-ignition engines

$$283 \text{ K} \leq T \leq 313 \text{ K}$$

6.2.2.2 Dry pressure, p_d

For all engines

$$80 \text{ kPa} \leq p_d \leq 110 \text{ kPa}$$

6.3 Determination of power correction factors

The test may be carried out in air-conditioned test rooms where the atmospheric conditions are controlled to equal the reference conditions.

Where an influencing parameter is controlled by an automatic device, no power correction for that parameter shall be applied, provided that the relevant parameter is within the relevant range of the device. This applies in particular to:

- automatic air temperature controls where the device is still operating at 298 K;
- automatic boost control, independent of atmospheric pressure, when the atmospheric pressure is such that the boost control is working;
- automatic fuel control, where the governor adjusts the fuel delivery for constant power output (by compensating for the influence of ambient pressure and temperature).

However, in the case of a), if the automatic air temperature device is fully closed at full load at 298 K (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; in the case of c), the fuel consumption for compression-ignition engines shall be corrected by the reciprocal of the power correction factor.

6.3.1 Naturally aspirated and pressure-charged spark-ignition engines - Factor α_a

The correction factor, α_a , for spark-ignition engines shall be as calculated from the formula

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

where

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

p_d is the dry atmospheric pressure, in kilopascals, i.e. the total barometric pressure minus the water vapor pressure.

This formula applies to carburetor equipped engines and to other engines where the management system is designed to maintain a relatively constant fuel/air ratio as ambient conditions change. For other engine types see 6.3.3.