

CHAPTER 6 : METHOD OF MEASURING NET POWER OF C.I. ENGINES

1 Scope : This Chapter describes the method for measuring the curve of the power at full load of an internal combustion engine as a function of engine speed and applies to compression ignition engines used for the propulsion of the vehicles, as defined in para 5.2.2 of Chapter 1 of this Part and para 5.2.2 of Chapter 1 .of Part V to this Rule.

2 Definitions :

2.1 "Net power" means the power obtained on a test bench at the end of the crankshaft or its equivalent (if power measurement can be carried out only on an engine with the gear box mounted, the efficiency of the gear-box shall be taken into account) at the corresponding engine speed with the auxiliaries listed in Table I;

2.2 "Standard production equipment" means any equipment provided by the manufacturer for a particular engine application.

3 Equipment :

3.1 Dynamometer and Engine Equipment :

The following equipment shall be used for emission tests of engines on engine dynamometers:

3.1.1 An engine dynamometer with adequate characteristics to perform the test described in Paragraph 4.5 below.

3.1.2 Measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and section flow resistance, air inlet temperature, atmospheric pressure, fuel temperature and humidity. The accuracy of these instruments shall satisfy the requirements given in 3.2 below.

3.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;

3.1.4 A non-insulated and uncooled exhaust system extending at least 0.5 m past the point where the exhaust probe is located, and presenting an exhaust back pressure within ± 650 Pa of the upper limit at the maximum rated power, as established by the engine manufacturer's sale and service literature for vehicle application;

3.1.5 An engine air inlet system presenting an air inlet restriction within $+ 300$ Pa of the upper limit for the engine operating condition which results in maximum air flow, as established by the engine manufacturer for an air cleaner, for the engine being tested.

3.2 Accuracy of Measurements :

3.2.1 Torque : $\pm 1\%$ of measured torque.

(The torque measuring system shall be calibrated to take friction losses into account. The accuracy in the lower half of the measuring range of the dynamometer bench may be $\pm 2\%$ of measured torque.)

3.2.2 Engine speed : $\pm 0,5\%$ of measured speed.

3.2.3 Fuel consumption : $\pm 1\%$ of measured consumption.

3.2.4 Fuel temperature : $\pm 2^{\circ}\text{K}$. Air temperature : $\pm 2^{\circ}\text{K}$.

3.2.5 Barometric pressure : ± 100 Pa.

3.2.6 Pressure to intake duct : ± 50 Pa

3.2.7 Pressure in exhaust duct : ± 200 Pa

4 Test for Measuring Net Engine Power :

4.1 Auxiliaries :

4.1.1 Auxiliaries to be fitted : During the test, the auxiliaries necessary for the engine operation in the intended application (as listed in Table I) shall be installed on the test bench as far as possible in the same position as in the intended application.

4.1.2 Auxiliaries to be removed : Certain vehicle accessories necessary only for the operation of the vehicle and which may be mounted on the engine shall be removed for the test. The following non-exhaustive list is given as a sample.

- Air compressor for brakes;
- Power steering compressor;
- Suspension compressor;
- Air-conditioning system.

Where accessories cannot be removed, the power they absorb in the unloaded condition may be determined and added to the measured engine power.

4.1.3 Compression ignition engine starting auxiliaries : For the auxiliaries used in starting compression ignition engines, the two following cases shall be considered :

4.1.3.1 Electrical starting : The generator is fitted and supplies, where necessary, the auxiliaries indispensable to the operation of the engine;

4.1.3.2 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.

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

4.2 Setting Conditions : The setting conditions for the test to determine the net power for the following -

- Setting of injection pump delivery system;
- Ignition or injection timing (timing curve);
- Governor setting;
- Anti-pollution devices;

are to be in accordance with the manufacturer's production specifications and used without further alteration for the particular application.

4.3 Test conditions :

4.3.1 The net power test shall consist of a run at fixed full- load fuel injection pump setting for diesel engines, the engine being equipped as specified in Table I.

4.3.2 Performance data shall be obtained under stabilised operating conditions with an adequate fresh air supply to the engine. The engines must 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 mentioned in para 5.2 below as possible in order to minimise magnitude of the correction factor.

4.3.3 The temperature of the inlet air to the engine (ambient air) shall be measured within 0,15 m upstream of the point of entry to the air cleaner, or if no air cleaner is used, within 0,15 m of the air inlet horn. The thermometer or thermocouple shall be shielded from radiant heat and placed directly in the 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.

4.3.4 No data shall be taken until torque, speed and temperatures have been maintained substantially constant for at least 1 minute.

4.3.5 The engine speed during a run or reading shall not deviate from the selected speed by more than $\pm 1\%$ or ± 10 per min, whichever is greater.

4.3.6 Observed brake load, fuel consumption and inlet air temperature data shall be taken simultaneously and shall be the average of two stabilised consecutive values which do not vary more than 2% for the brake load and fuel consumption.

4.3.7 The temperature of the coolant at the outlet from the engine shall be kept within ± 5 deg.K from the upper thermostatically controlled temperature specified by the manufacturer. If no temperature is specified by the manufacturer, the temperature

shall be $353 \text{ deg.K} \pm 5 \text{ deg.K}$. For air-cooled engines, the temperature at a point indicated by the manufacturer shall be kept within $\pm 20 \text{ deg.K}$ of the maximum value specified by the manufacturer in the reference conditions.

4.3.8 The fuel temperature shall be measured at the fuel injection system and maintained within the limits established by the engine manufacturer.

4.3.9 The temperature of the lubricating oil measured in the oilsump or at the outlet from the oil cooler, if fitted, shall be maintained within the limits established by the engine manufacturer.

4.3.10 An auxiliary regulating system may be used if necessary to maintain the temperatures within the limits specified in Paragraphs 4.3.7, 4.3.8 and 4.3.9 above.

4.4 Fuel : The fuel used shall be the reference fuel as per Chapter 5 of this Part.

4.5 Test procedure : Measurements shall be taken at a sufficient number of engine speeds to define correctly the power curve between the maximum and the minimum rated speeds recommended by the manufacturer. This range of speeds must include the speed of revolution at which the engine produce its maximum power. The average of at least two stabilised measurements is to be determined.

4.6 Data to be recorded : Data to be recorded are those indicated in the Table II.

5 Power Correction Factors :

5.1 Definition : The power correction factor is the coefficient by which the measured power must be multiplied to determine the engine power under the reference atmospheric conditions specified in Para 5.2.

$$P_0 = \alpha P$$

where :

P_0 is the corrected power (i.e. power under reference atmospheric conditions);

α is the correction factor

P is the measured power (test power).

5.2 Reference atmospheric conditions :

5.2.1 Temperature (T) : 298° K

5.2.2 Dry pressure (P_{S0}) : 99 kPa .

Note : The dry pressure is based on a total pressure of 100 kPa and a water vapour pressure of 1 kPa .

5.3 Test atmospheric conditions :

The atmospheric conditions during the test shall be the following :

5.3.1 Temperature (T) : Between 283K and 313K

5.3.2 Pressure (P) : Between 80 kPa and 110 kPa

5.4 Determination of correction factor :

(The tests may be carried out in air-conditioned test rooms where the atmospheric conditions may be controlled.)

5.4.1 The power correction factor α for diesel engines at constant fuel delivery is obtained by applying the formula :

$$\alpha = f_a^{f_m}$$

where

f_a - the atmospheric factor

f_m - the characteristic parameter for each type of engine and adjustment

5.4.2 Atmospheric factor (f_a) :

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

5.4.2.2 Naturally aspirated and mechanically pressure charged engines :

$$f_a = (99/P_s) * (T/298)^{0.7}$$

5.4.2.3 Turbocharged engines with or without cooling of charge air :

$$f_a = (99/P_s)^{0.7} * (T/298)^{1.5}$$

5.4.3 Engine Factor (f_m) :

f_m is a function of Q_c (fuel flow corrected) as follows :

$$f_m = 0.036 Q_c - 1.14$$

where

Q_c - Q/r and

Q - the fuel delivery in milligrams/cycle per litre of engine swept volume (mg/l.cycle)

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

This formula is valid when Q_c is $40 \leq Q_c \leq 65$.

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, as given below:

5.4.4 Limitations in use of correction formula : This correction formula is only applicable if $0.9 \leq \alpha \leq 1.1$.

5.4.5 If these limits are exceeded, the corrected value obtained shall be given, and the test conditions (temperature and pressure) precisely stated in the Test Report.

6 Test Report : The test report shall contain the results and all the calculations required to find the net power, as listed in the Table II below, together with the characteristics of the engine listed in Chapter 2 to this Part.

TABLE I - Auxiliaries to be fitted for the test to determine net power of engine

No.	Auxiliaries	Fitted for net power test
1.	Intake system	
	Intake manifold	} Yes, standard production equipment
	Crankcase emission control system	
	Air filter	} Yes, standard production equipment
	Intake silencer	
	Speed limiting device	

(The complete intake system shall be fitted as provided for the intended application :

Where there is a risk of an appreciable effect on the engine power;

In the case of two-stroke and positive-ignition engines;
When the manufacturer requests that this should be done.

In other cases, an equivalent system may be used and a check should be made to ascertain that the intake pressure does not

differ by more than 100 Pa from the limit specified by the manufacturer for a clean air filter).

- 2. Induction heating device of intake manifold Yes, standard production equipment. If possible, to be set in the most favourable position.

3. Exhaust system

- Exhaust purifier
 - Exhaust manifold
 - Supercharging device
 - Connecting pipes *
 - Silencer *
 - Tail pipe *
- } Yes, standard production equipment

Exhaust brake :
If an exhaust brake is incorporated in the engine, the throttle valve must be fixed in a fully open position.

* The complete exhaust system shall be fitted as provided for the intended application : Where there is a risk of an appreciable effect on the engine power;

In the case of two-stroke and positive-ignition engines; When the manufacturer requests that this should be done.

In other cases, an equivalent system may be installed provided the pressure measured at the exit of the engine exhaust system does not differ by more than 1 000 Pa from that specified by the manufacturer. The exit from the engine exhaust system is defined as a point 150 mm down-stream from the termination of the part of the exhaust system mounted on the engine.

- 4. Fuel supply pump :
Yes, standard production equipment The fuel pressure may be adjusted,if necessary to reproduce the pressures existing in the particular engine application (particularly when a fuel return system is used).

5. Fuel injection equipment

- Prefilter
 - Filter
 - Pump
 - High Pressure pipe
 - Injector
 - Air intake valve *
- } Yes, standard production equipment

If fitted

Electronic control system,
 Air flow meter, etc
 (if fitted)
 Governor/Control system
 Automatic full-load stop
 for the control rack
 depending on atmospheric
 conditions.

* The air intake 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 injected fuel.

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| 6. | Liquid cooling equipment
Engine bonnet
Bonnet air outlet
Radiator | } | No |
| | * Fan
Fan cowl
Water pump | } | Yes, standard production
equipment |

* Thermostat

(*) The radiator, the fan, the fan cowl, the water pump and the thermostat shall be located on the test bench in the same relative positions as on the vehicle. 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 remain 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), must 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 reference atmospheric conditions defined in paragraph 5.2, should be deducted from the corrected power. 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 or blower running at maximum slip.

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

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| 7. | Air cooling

Cowl | } | Yes, standard production |
|----|-------------------------|---|--------------------------|

equipment

* Blower

Temperature regulating device } Yes, standard production equipment

(*) The radiator, the fan, the fan cowl, the water pump and the thermostat shall be located on the test bench in the same relative positions as on the vehicle. 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 remain 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), must 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 Paragraph 5.2, should be deducted from the corrected power.

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 or blower running at maximum slip.

- 8. Electrical equipment Yes, standard production equipment.

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 must be used.

- 9. Supercharging equipment

(if fitted) Compressor driven either directly by the engine, and/or by the exhaust gases } Yes, standard production equipment

* Charge air cooler Coolant pump or fan (engine driven) Coolant flow control }

devices (if fitted)

(*) Charge air cooled engines shall be tested with charge air cooling, whether liquid or air cooled, but if the engine manufacturer prefers, a test bench system may replace the air cooled cooler. In either case, the measurement of power at each speed shall be made with the same pressure drop and temperature drop of the engine air across the charge air cooler on the test bench system as those specified by the manufacturer for the system on the complete vehicle.

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| 10. | Auxiliary test bench fan | Yes, if necessary |
| 11. | Anti-pollution devices | Yes, standard production equipment |

They may include, for example, EGR (Exhaust Gas recirculation system, catalytic converter, thermal reactor, secondary air supply system and fuel evaporation protecting system.

TABLE - II : STATEMENT OF THE RESULTS OF TESTS FOR MEASURING NET ENGINE POWER

This information is to be supplied by the manufacturer simultaneously with the identification sheet constituting Chapter 2 to this Part. If the test under this Rule is a bench test of the engine, this form shall be completed by the laboratory performing the test.

1.0	Test Conditions	-----
1.1	Pressures measured at maximum power	-----
1.1.1	Total barometric pressure	----- Pa
1.1.2	Water vapour pressure	----- Pa
1.1.3	Exhaust pressure	-----
1.2	Temperatures measured at maximum power	-----k
1.2.1	of the intake air	----- K
1.2.2	at the outlet of the engine intercooler	----- K
1.2.3	of the cooling fluid :	-----
1.2.3.1	at the engine cooling fluid outlet	----- K
	(strike out what does not apply)	
1.2.3.2	at the reference point in the case of air cooling (strike out what does not apply)	-----K
1.2.4	of the lubricating oil deg.K (indicate point of measurement)	-----
1.2.5	of the fuel	----- K
1.2.5.1	of the fuel pump inlet	----- K
1.2.5.2	in the fuel-consumption measuring device	----- K
1.3	Characteristics of the dynamometer :	-----
1.3.1	Make :	-----
	Model:	-----
1.3.2	Type :	-----

2.0	Fuel		-----
2.1	Make :		-----
2.2	Specification of fuel used :		-----
2.3	Cetane index (IS1448 Part 9)		-----
2.4	Specific density :		-----g/cm ³ at 288 ⁰ K
2.5	Lower calorific value :		-----kJ/kg
3.0	Lubricant		-----
3.1	Make :		-----
3.2	Specification :		-----
3.3	SAE viscosity :		-----
4.0	Detailed results of measurements		-----
4.1	Statements of results of net power measurement test (The characteristic curves of the net power and the net torque shall be drawn as a function of the engine speed)		-----
4.1.1	Engine speed, 1/min		-----
4.1.2	Measured torque, Nm		-----
4.1.3	Measured power, kW		-----
4.1.4	Measured fuel flow, g/kWh		-----
4.1.5	Measured smoke index, m		-----
4.1.6	Barometric pressure, kPa		-----
4.1.7	Water vapour pressure, kPa		-----
4.1.8	Inlet air temperature, ⁰ K		-----
4.1.9	Power to be added for auxiliaries in excess of	No.1	-----

	Table I, kW	No.2	-----

		No.3	-----

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- 4.1.10 Power correction factor, -----
- 4.1.11 Corrected brake power, kW
(with/without fan) -----
- 4.1.12 Power of fan, kW
(to be subtracted if fan not
fitted) -----
- 4.1.13 Net power, kW -----
- 4.1.14 Net torque, Nm -----
- 4.1.15 Corrected specific fuel
consumption g/kWh
(Calculated with the net
power for compression
ignition and positive-
ignition engines, in the
latter case multiplied by the
power correction factor). -----
- 4.1.16 Smoke index m^{-1} -----
- 4.1.17 Cooling liquid temperature at outlet, K -----
- 4.1.18 Lubricating oil temperature at measuring point, K -----
- 4.1.19 Air temperature after supercharger, K (If applicable) -----
- 4.1.20 Fuel temperature at injection pump inlet, K -----
- 4.1.21 Air temperature after charge air cooler, K (If applicable) -----
- 4.1.22 Pressure after supercharger, kPa
(If applicable) -----
- 4.1.23 Pressure after charge air cooler, kPa -----
- 4.2 Maximum net power : ----- kW at 1/ .min
- 4.3 Maximum net torque: ----- Nm at 1/ .min
- 5.0 Engine submitted for testing on : -----
- 6.0 Technical Agency conducting tests: -----