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Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”


“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartrhari—Nitisatakam
“Knowledge is such a treasure which cannot be stolen”
Indian Standard

AUTOMOTIVE VEHICLES — PERFORMANCE REQUIREMENTS (MEASUREMENT OF POWER, SFC, OPACITY) OF POSITIVE AND COMPRESSION IGNITION ENGINES — METHOD OF TEST

ICS 43.060.01; 19.020

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 1999
FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Automotive Primemovers Sectional Committee had been approved by the Transport Engineering Division Council.

There is a need to have a uniform procedure for defining and measuring performance of positive and compression ignition engines used for automotive applications inline with international standards.

While formulating the standard assistance has been derived from the following International Standards:

- ISO 1585 : 1992 Road vehicles — Engines test code — Net power
- ISO 4164 : 1978 Road vehicles — Mopeds — Engine test code — Net power
- ECE R-24 Uniform provisions concerning the approval of vehicles equipped with a positive ignition engine or with a compression ignition engine with regard to the emission of gaseous pollutants by the engine — Method of measuring the power of positive ignition engines — Method of measuring the fuel consumption of vehicles.

While formulating the standard considerable assistance has also been derived from the following Indian Standards and also from the Ranganathan Committee Report:

- IS 8118 : 1998 Automotive vehicles — Opacity (smoke) of exhaust gas from vehicles equipped with compression ignition engines operating under free acceleration — Method of measurement (second revision)
- IS 10003 : 1988 Compression ignition (diesel) engines for automotive application (first revision)
- IS 10004 : 1981 Performance requirements for spark ignition engines for automotive purposes
- IS 12455 : 1988 Performance requirements of air-cooled spark ignition automotive engines
- Annex 4 of Details of Standards for Emission of Visible Pollutants from Diesel Vehicles and Test Procedures Effective from 01.04.1991

Presently the methods of test for internal combustion engines, both with constant and variable speed, are covered under IS 10000 series of standards. However, the methods of tests for variable speed spark and internal combustion engines have been covered in this standard after aligning the same with the existing ISO/IEC directives. The relevant requirements for the constant speed internal combustion engines will be taken up for revision by the Internal Combustion Sectional Committee, HM 19.

The composition of the technical committee responsible for the formulation of this standard is given in Annex C.
Indian Standard

AUTOMOTIVE VEHICLES — PERFORMANCE REQUIREMENTS (MEASUREMENT OF POWER, SFC, OPACITY) OF POSITIVE AND COMPRESSION IGNITION ENGINES — METHOD OF TEST

1 SCOPE

This standard specifies the method for measurement of performance such as the power, brake specific fuel consumption at full load of an internal combustion engines (both positive and compression ignition engines) used for automotive vehicles as a function of engine speed. This standard also covers the measurement of opacity (smoke) of the exhaust gas of compression ignition engines.

2 REFERENCES

The following Indian Standards contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

<table>
<thead>
<tr>
<th>IS No.</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>8118 : 1998</td>
<td>Automotive vehicles — Opacity (smoke) of exhaust gas from in-service vehicles equipped with compression ignition engines operating under free acceleration — Method of measurement (second revision)</td>
</tr>
<tr>
<td>14553 : 1998</td>
<td>Automotive vehicles — Apparatus for the measurement of opacity (smoke) of exhaust gas from vehicles equipped with compression ignition engines — Specification</td>
</tr>
</tbody>
</table>

3 TERMINOLOGY

For the purpose of the standard the following definitions shall apply.

3.1 Compression Ignition Engine

Means an internal combustion engine in which ignition occurs by the temperature of the cylinder contents resulting solely from their compression.

3.2 Positive Ignition Engine

Means an internal combustion engine in which the combustion of the air/fuel mixture is initiated at given instant by a hot spot, usually an electric spark.

3.3 Engine Speed

The number of revolutions of crankshaft in a given period of time.

3.4 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 as declared by the manufacturer, the efficiency of the gear-box shall be taken into account) at the corresponding engine speed with the auxiliaries listed in Table 1, and determined under reference atmospheric conditions, specified in 6.2 expressed in kW.

3.5 Engine Torque

Means torque measured 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 as declared by the manufacturer, the efficiency of the gear-box shall be taken into account) at the corresponding engine speed with the auxiliaries listed in Table 1, and determined under reference atmospheric conditions, specified in 6.2 expressed in kW.

3.6 Specific Fuel Consumption

The quantity of fuel consumed by the engine expressed in g/kWh.

3.7 Intake Air Depression

The mean pressure head below atmospheric (suction) pressure existing in the intake manifold with an air cleaner fitted expressed in kPa.

3.8 Exhaust Back Pressure

The mean static pressure head existing in the exhaust pipe of an engine test bed installation measured at a point in the pipe 150 mm downstream from the outlet flange of the engine manifold/turbo charge outlet expressed in kPa.

3.9 Lubricating Oil Pressure

Oil pressure at given points of the lubricating system
3.10 Air Intake Temperature

The temperature expressed in Kelvin (K) measured with in 150 mm of the air filter.

3.11 Exhaust Gas Temperature

Temperature of the exhaust gas measured at a point in the exhaust pipe 150 mm downstream from the outlet flange of the exhaust manifold or 150 mm from the outlet flange of the turbo charger expressed in Kelvin (K).

3.12 Coolant Temperature

Temperature(s) at given point(s) such as after the thermostat or of the fluid cooling system(s) expressed in Kelvin (K).

3.13 Lubricating Oil Temperature

Oil temperature(s) at given point(s) of the lubricating system(s) expressed in Kelvin (K).

3.14 Fuel Temperature

a) In case of spark ignition engines the fuel temperature shall be measured as near as possible to the inlet of the carburettor or fuel injection assembly.

b) In case of compression ignition engines, the fuel temperature shall be measured at the inlet to the injection pump. At the request of the manufacturer the fuel temperature measurement can be made at another point in the pump representative of the engine operating condition.

3.15 Smoke Density

Means the light absorption coefficient of the exhaust gases emitted by the vehicle expressed in terms of m⁻¹ or in other units such as Hartridge, percent opacity. Fig. 1 of this standard shows the relation between light absorption coefficient expressed in m⁻¹, percentage opacity, Hartridge Smoke Unit (HSU) and Bosch Smoke Units.

3.16 Light Absorption Coefficient

Means the percentage of light absorption in one metre length of measurement tube of the smoke meter. The light absorption coefficient is calculated by:

\[ \varphi = \varphi_0 e^{-kl} \]

where

- \( L \) — effective length of light path through the gas in metres.
- \( \varphi_0 \) — light flux at the end of the measurement chamber when filled with clean air in lumens.
- \( \varphi \) — light flux at the end of the measurement chamber when filled with smoke in lumens.

In case ‘\( L \)’, the effective length of the light patch of the opacimeter can not be assessed directly from geometry, this can be determined by the relation with the 0-100 light obscuration scale by the following formula:

\[ k = \frac{-1}{L} \log_e \left(1 - \frac{N}{100}\right) \]

where

- \( k \) — value of light absorption coefficient in m⁻¹.
- \( L \) — effective length of light path through the gas in metres.
- \( N \) — reading on the linear scale.

3.17 Opacity Meter

Means an instrument for continuous measurement of the light absorption coefficient of the exhaust gases emitted by automotive vehicles.

3.18 Maximum Rated Speed

Means the maximum speed permitted by governor at full load, unless otherwise declared by the manufacturer.

3.19 Minimum Rated Speed

Means either the highest of the following three engine speeds:

- 45 percent of maximum net power speed,
- 1 000 rev/min,
- minimum speed permitted by the idling control, or
- such lower speed as the manufacturer may specify.

3.20 Cold Start Device

Means a device which enriches the fuel-air mixture of the engine temporarily and thus assist in engine start up.

3.21 Starting Aid

Means a device which assists the engine start up without enrichment of the fuel mixture such as glow plug, change of injection timing.

4 TEST EQUIPMENT

4.1 Dynamometer and Engine Equipment

The following equipment shall be used for performance tests of engines on engine dynamometers.

4.1.1 An engine dynamometer with adequate characteristics to perform the test specified in 5.5.

4.1.2 Measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, spark plug temperature, exhaust gas pressure and section flow resistance, air inlet
NOTE — The correlation between Bosch smoke units and other units has been established only for steady state conditions. Hence, this is not applicable for the free acceleration test.

**FIG. 1 DIESEL ENGINE EXHAUST SMOKE VALUE CORRELATION CHART**
temperature, atmospheric pressure, fuel temperature and humidity. The accuracy of these instruments shall satisfy the requirements specified in 4.2.

4.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the specified engine tests.

4.2 Accuracy of Measuring Equipment and Instruments

a) Torque ± 1 percent 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 ±2 percent of measured torque.)

b) Engine speed ± 0.5 percent of measured speed
c) Fuel consumption ± 1 percent of measured consumption
d) Fuel temperature ± 2 K
e) Air temperature ± 2 K
f) Barometric pressure ± 100 Pa
g) Pressure in intake duct
h) Pressure in exhaust duct
j) Smoke (opacity) ± 0.05/m

5 PERFORMANCE MEASUREMENT

5.1 Auxiliaries

5.1.1 Auxiliaries to be Fitted

During the test auxiliaries necessary to make 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 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 an example:

- air compressor for brakes;
- power steering pump;
- suspension compressor; and
- air-conditioning system.

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 shall be 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 shall be fitted to supply these accessories, otherwise, it is removed.

In either case, the system for producing and accumulating the energy necessary for starting shall be fitted and operated in the unloaded condition.

5.2 Setting Conditions

The setting conditions for the test for determination of net power are indicated in Table 1.

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Setting Condition</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Setting of carburettor(s)</td>
<td>In accordance with the manufacturer’s production specifications and used without further alteration for the particular application</td>
</tr>
<tr>
<td>ii)</td>
<td>Setting of injection pump delivery system</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>Ignition or injection timing (timing curve)</td>
<td></td>
</tr>
<tr>
<td>iv)</td>
<td>Governor setting</td>
<td></td>
</tr>
<tr>
<td>v)</td>
<td>Anti-pollution devices</td>
<td></td>
</tr>
<tr>
<td>vi)</td>
<td>Boost control</td>
<td></td>
</tr>
</tbody>
</table>

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 the 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, started and warmed up 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 correction factor.

5.3.3 The temperature of the inlet air to the engine (ambient air), shall be measured within 0.15 m upstream of the air inlet ductwork. The thermometer or thermocouple shall be shielded from radiant heat and located directly in the airstream. It shall also be shielded from fuel spray back. A sufficient number of locations shall be used to give a representative of the average inlet temperature.

5.3.4 The inlet depression shall be measured downstream of the entry ducts, air filter, inlet silencer;
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 flanger(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, speed and temperature have been maintained substantially constant for at least one minute.

5.3.8 The engine speed during a run or reading shall not deviate from the selected speed by more than ±1 percent or ±10 min⁻¹, whichever is greater.

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

5.3.10 The coolant temperature at the engine outlet shall be kept within ± 5 K of the upper thermostatically controlled temperature specified by the manufacturer. If no temperature is so specified, the temperature shall be 353 ± 5 K. For air-cooled engines, the temperature at a point indicated by the manufacturer shall be kept within 0 to – 20 K of the maximum value specified by the manufacturer in 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 carburettor or assembly of fuel injectors. Fuel temperature shall be maintained within ±5 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 ± 5 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 ± 3 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 considered as 313 ± 3 K.

5.3.12 The lubricant temperature shall be measured at the oil gallery inlet or the oil cooler outlet if fitted, unless some other measuring location 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 temperature within limits specified in 5.3.10, 5.3.11 and 5.3.12.

5.4 Fuel

The requirements of reference fuel shall be the same as notified by the statutory authorities. A commercially available fuel may also be used provided that the characteristics are such that it does not contain any smoke suppressant additives.

5.5 Test Procedure

Measurements shall be taken at a sufficient number of engine speeds not less than six, to define correctly the power curve between the maximum and the minimum rated speeds recommended by the manufacturer. This range of speeds shall include the speed of revolution at which the engine produces its maximum power. The average of at least two stabilised measurements shall be determined.

5.6 Record of Data

The data indicated in Annex A shall be recorded.

6 POWER CORRECTION FACTORS

6.1 Determination of Factor c₁ 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 that is at reference conditions is given by the following formula:

\[ P_0 = \alpha P \]

where

- \( P_0 \) — the net power under reference atmospheric conditions,
- \( \alpha \) — the correction factor (\( \alpha_{a} \) being the correction factor for spark ignition engines and \( \alpha_{c} \) for compression ignition engines), and
- \( P \) — the measured (observed) power.

6.2 Reference Atmospheric Conditions

6.2.1 Temperature (\( T \)) — 298 K

6.2.2 Dry pressure (\( P_{o} \)) — 99 kPa.

NOTE — The dry pressure is based on a total pressure of 100 kPa and a water vapour pressure of 1 kPa.
6.3 Test Atmospheric Conditions

The atmospheric conditions during the test shall be the following:

6.3.1 Temperature ($T$) Between 283 K and 313 K, for compression ignition engines. Between 288 K and 308 K, for positive ignition engines.

6.3.2 Dry pressure ($P$) Between 80 kPa and 110 kPa for all engines.

6.4 Determination of Power Correction Factor ($aa$ or $ad$)

a) The test may be carried out in air-conditioned test rooms or by providing conditioned air to inlet of the engine, where the atmospheric conditions are controlled to equal the reference conditions.

b) 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:
   i) automatic air temperature controls where the device is still operating at 25°C;
   ii) automatic boost control, independent of atmospheric pressure, when the atmospheric pressure is such that the boost control is working; and
   iii) automatic fuel control where the governor adjusts the fuel flow for constant power output (by compensating for the influence of ambient pressure and temperature).

However, in the case of (i), if the automatic air temperature device is fully closed at full load at 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. In the case of (iii), the fuel flow for compression ignition engines shall be corrected by the reciprocal of the power correction factor.

6.4.1 Positive Ignition Engine (Naturally Aspirated or Supercharged)

The correction factor ($aa$) is obtained by applying the formula:

$$ f_a = (99/P_s)^{1/2} \times (T/298)^{0.6} $$

where

$P_s$ — the dry atmospheric pressure in kPa, that is the total barometric pressure minus water vapour pressure; and

$T$ — the absolute temperature in kelvin (K) at the engine air inlet.

The formula applies to carburetted engines and to other engines where the management system is designed to maintain relatively constant fuel/air ratio as ambient conditions change. For other engine types see 6.4.3.

6.4.1.1 For a test to be valid, the correction factor $ad$ shall be such that:

$$ 0.93 \leq ad \leq 1.07 $$

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

6.4.2 Compression Ignition Engines

Correction Factor ($ad$)

The power/torque correction factor, $ad$ for diesel engines at constant fuel delivery setting is obtained by applying the following formula:

$$ ad = (f_a)^{f_m} $$

where

$f_a$ — the atmospheric factor (see 6.4.2.1), and

$f_m$ — the characteristic parameter for each type of engine and its adjustment (see 6.4.2.2).

6.4.2.1 Atmospheric factor ($f_a$)

This factor indicates the effect of environmental conditions (pressure, temperature and humidity) on the air drawn-in by the engine. This shall be as calculated from the formula in (a), (b) or (c):

a) Naturally aspirated and mechanically pressure charged engines and turbocharged engines with waste gates operating:

$$ f_a = (99/P_t) \times (T/298)^{0.7} $$

where

$P_t$ — the dry atmospheric pressure in kPa, that is the total barometric pressure minus water vapour pressure; and

$T$ — the absolute temperature in kelvin (K) at the engine air inlet.

b) Turbocharged engines without cooling of charge air or with charge cooling by air/air cooler:

$$ f_a = (99/P_t)^{0.9} \times (T/298)^{1.2} $$

NOTE — For engine speeds when the waste gate of a turbocharged engine is not operating, formula (a) or (b) is used, depending on the type of charge air cooling, if any.

c) Turbocharged engines with charge air cooling by engine coolant:

$$ f_a = (99/P_t)^{0.9} \times (T/298)^{0.9} $$
For a test to be recognized as valid, the parameter $f_\alpha$ shall be in between 0.98 and 1.02.

6.4.2.2 Engine factor ($f_\alpha$)

Within the limits established for $\alpha d$ in 6.4.2, the engine factor, $f_\alpha$, is a function of the corrected fuel delivery parameter, $q_\alpha$, and is calculated from the formula:

$$f_\alpha = 0.036 q_\alpha - 1.14$$

where

$$q_\alpha = \frac{q}{r}$$

in which

$q$ is the fuel delivery parameter, in milligrams per cycle per litre of engine swept volume (mg/l.cycle), and is equal to:

$$\left(\frac{Z}{r}\right) \times \left(\frac{\text{fuel flow in g/s}}{\text{displacement in l}} \times \text{engine speed in min}^{-1}\right)$$

where

$Z = 120,000$ for four-stroke engines and $Z = 60,000$ for two-stroke engines;

$r$ is the ratio between the absolute static pressure at the outlet of the pressure charger, or charge air cooler if fitted, and the ambient pressure ($r - 1$ for naturally aspirated engines).

The formula for the engine factor, $f_\alpha$, is only for a $q_\alpha$ value between 42 mg/(l.cycle) $\leq q_\alpha \leq 65$ mg/(l.cycle). For value less than 42 mg/(l.cycle), a constant value of 0.3 shall be taken for $f_\alpha$, while for $q_\alpha$ values greater than 65 mg/(l.cycle), constant value of 1.2 shall be taken for $f_\alpha$ (see Fig. 2).

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

6.4.3 Other Types of Engine

For engines not covered by 6.4.1 and 6.4.2 a correction factor equal to 1 shall be applied when the ambient air density do not vary by more than $\pm$ 2 percent from the density at the reference conditions (298 K and 99 kPa). When ambient air density beyond these limits, no correction shall be applied, but conditions shall be stated in the test report.

7 CALCULATION OF SPECIFIC FUEL CONSUMPTION (SFC)

7.1 The SFC is calculated from measured fuel consumption in g/h and the corrected net power.

7.2 In case of two-stroke positive ignition engines where pre-mixing of lubricating oil and fuel is carried out, the specified fuel consumption shall be calculated taking the specific gravity of the fuel alone in the combination (not the specific gravity of the fuel mixed with lubricating oil). However, while carrying out the arithmetical calculation for determining the gravimetric specific fuel consumption, a due allowance for the volume of lubricating oil shall be made.

Example:

If $V$ ml of fuel, containing $v$ percent of lubricating oil, takes $t$ seconds for being consumed while the engine is developing $P$ kW of corrected net power and the specific gravity of the fuel is $s$ g/ml, then the specific fuel consumption is given by the following formula:

$$SFC = \frac{V}{(1+ v/100)} \times \frac{(3,600 s)}{(P, t)}$$

where

$SFC$ — specific fuel consumption in g/kWh,

$V$ — quantity of fuel in ml,

$s$ — specific gravity of the fuel in g/ml,

$v$ — percent of lubricant oil,

$P$ — corrected net power in kW, and

$t$ — time taken in seconds.

8 MEASUREMENT OF OPACITY OF THE EXHAUST GAS (SMOKE) FOR COMPRESSION IGNITION ENGINES

8.1 Measurement of Opacity (Smoke) at Steady Speeds and at Full Load

8.1.1 Measurement Principle

The opacity of the exhaust gases produced by the engine shall be measured with the engine running...
8.1.2 Sampling and Measuring Apparatus

The light-absorption coefficient of the exhaust gases shall be measured with an opacimeter satisfying the conditions specified in IS 8118 and installed in conformity with the conditions laid down therein.

8.1.3 Installation of Opacimeter

8.1.3.1 Installation for full-load tests

8.1.3.2 The ratio of the cross-sectional area of the probe to that of the exhaust pipe shall not be less than 0.05. The back pressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water column).

8.1.3.3 The probe shall be a tube with an open end facing forward in the axis of the exhaust pipe or of the extension pipe so that, if \( D \) is the diameter of the exhaust pipe at the opening, the end of the probe is situated in a straight portion at least 6\( D \) in length upstream of the sampling point and 3\( D \) in length downstream. If an extension pipe is used, no air shall be allowed to enter the joint.

8.1.3.4 The pressure in the exhaust pipe and the characteristics of the pressure drop in the sampling line shall be such that the probe collects a sample sensibly equivalent to that generally obtained by isokinetic sampling.

8.1.3.5 If necessary, an expansion tank of compact design and of sufficient capacity to damp the pulsations may be incorporated in the sampling line as near to the probe as possible. A cooler may also be fitted. The design of the expansion tank and cooler shall not unduly disturb the composition of the exhaust gas.

8.1.3.6 A butterfly valve or other means of increasing the sampling pressure may be placed in the exhaust pipe at least 3\( D \) downstream from the sampling probe.

8.1.3.7 The connecting pipes between the probe, the cooling device, the expansion tank (if required) and the opacimeter shall be as short as possible while satisfying the pressure and temperature requirements specified. The pipe shall be inclined upwards from the sampling point to the opacimeter and sharp bends where soot is likely to accumulate shall be avoided. If not embodied in the opacimeter, a by-pass valve shall be provided upstream.

8.1.3.8 A check shall be carried out during the test to ensure that the requirements concerning pressure and temperature in the measuring chamber, as specified in IS 14553.

8.1.4 Evaluation of the Absorption Coefficient

8.1.4.1 For each of the engine speeds at which the absorption coefficient is measured in accordance with 8.1.2, the nominal gas flow shall be calculated by means of the following formulae:

For two-stroke engines:

\[
G = V \times n/60
\]

For four-stroke engines

\[
G = V \times n/120
\]

where

\( G \) — nominal gas flow, in litres per second, (l/s);

\( V \) — cylinder capacity of the engine, in litres, (l); and

\( n \) — engine speed, in revolutions per minute (min)\(^{-1}\).

8.1.4.2 For the test to be valid the atmospheric factor \( f_a \) shall be between 0.98 and 1.02.

8.2 Measurement of Opacity (Smoke) During Free Acceleration

8.2.1 The test shall be carried out on an engine installed on a test bench immediately after the test for measurement of opacity under full load at steady speed specified in 8.1 and it shall also be ensured that the cooling water and the lubricating oil shall be at the normal temperatures stated by the manufacturer.

8.2.2 Test Procedures

The test procedure followed for carrying out the test is the same as given in IS 8118.

9 TEST REPORT

The test report shall contain the results and all the calculations required to determine the net power, specific fuel consumption and smoke as listed in Annex A, together with the characteristics of the engine which is to be declared by the manufacturer, shall contain at least the details given in Annex B.

10 TOLERANCES

10.1 Declared Values

10.1.1 Power

\( a \) Declared single maximum power engine speed \( (n_p) \)

At least at one engine speed which is in the range of \( n_p + n_s \), where \( n_s \) is the speed tolerance specified by the manufacturer. If not specified, \( n_s \) shall be ± 2 percent. The corrected power shall be not less than \((100 - a) \) percent (see Fig. 3) of the declared power.
At no engine speed shall the corrected power be more than \((100 + a)\) percent (see Fig. 3) of the declared power (see 10.1.4).

NOTE — In normal cases near the declared maximum power engine speed, it is recommended that measurements be made in steps no smaller than 3 percent of the declared maximum power engine speed or 3 percent of engine speed, \(n_p\), of the power range as appropriate.

In no case shall the corrected power differ from the declared power at a given engine speed by more than \(d\) percent (see 10.1.4).

\[ n_p = \text{speed tolerance specified by manufacturer. If not specified, } n_p = \pm 2\% \]

\[ 2\% < n_p < 2\% \]

**Fig. 3 Declared Single Engine Speed Maximum Power Graph**

- b) Declared maximum power engine speed range \((n_p - n_p)\)

Within the engine speed range \((n_p - n_p)\) percent to \((n_p - n_p)\) percent the corrected power shall be not less than \((100 - a)\) percent (see Fig. 4) of the declared power (see 10.1.4), where \(n_p\) is the speed tolerance specified by the manufacturer. If not specified \(n_p\) shall be \(\pm 2\%\).

- At no engine speed shall the corrected power be more than \((100 + a)\) percent (see Fig. 4) of the declared power (see 10.1.4).

NOTE — In normal cases near the declared maximum power engine speed, it is recommended that measurements be made in steps no smaller than 3 percent of the declared maximum power engine speed or 3 percent of engine speed, \(n_p\), of the power range as appropriate.

In no case shall be corrected power differ from the declared power at a given engine speed by more than \(d\) percent (see 10.1.4).

**10.1.2 Torque**

- a) Declared single maximum torque engine speed \((n_t)\)

- At least at one speed, which is in the range of \(n_t \pm n_t\) percent, where \(n_t\) is the speed tolerance specified by the manufacturer. If not specified \(n_t\) shall be \(\pm 2\%\). The corrected torque shall be not less than \((100 - b)\) percent (see Fig. 5) of the declared maximum torque (see 10.1.4).

- At no engine speed shall the corrected torque be more than \((100 + b)\) percent (see Fig. 5) of the declared maximum torque (see 10.1.4).

NOTE — In normal cases near the declared maximum torque engine speed, it is recommended that measurements be made in steps no smaller than 3 percent of the declared maximum torque engine speed or 3 percent of maximum engine speed, \(n_t\), of the torque range as appropriate.

In no case shall the corrected torque differ from the declared torque at a given engine speed by more than \(d\) percent (see 10.1.4).

**Fig. 4 Declared Engine Speed Range Maximum Power Graph**

**Fig. 5 Declared Single Engine Speed Maximum Torque Graph**
b) Declared maximum torque engine speed range, 
\( (n_{11} - n_{12}) \)

- Within the engine speed range \( (n_{11} + n_{12}) \) percent to \( (n_{11} + n_{12}) \) percent, where \( n_i \) is the speed tolerance specified by the manufacturer. If not specified \( n_i \) shall be ± 2 percent. The corrected torque shall be not less than \((100 - b)\) percent (see Fig. 6) of the declared maximum torque (see 10.1.4).

- At no engine speed shall the corrected torque be more than \((100 + b)\) percent (see Fig. 6) of the declared maximum torque (see 10.1.4).

10.1.3 Specific Fuel Consumption

A declared specific fuel consumption at a declared engine speed (range) is assumed to be verified, if the specific fuel consumption calculated during test is not more than e percent greater than the declared specific fuel consumption (see 10.1.4).

10.1.4 Numerical Tolerances

The numerical tolerances are given in Table 2.

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>( a% )</th>
<th>( b% )</th>
<th>( c% )</th>
<th>( d% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive ignition engines used for 2 and 3 wheelers, with declared power not exceeding 1 kW</td>
<td>±10</td>
<td>±20</td>
<td>±10</td>
<td>±20</td>
</tr>
<tr>
<td>Positive ignition engines used for 2 and 3 wheelers, with declared power exceeding 1 kW</td>
<td>±5</td>
<td>±10</td>
<td>±5</td>
<td>±10</td>
</tr>
<tr>
<td>Single cylinder compression ignition engines</td>
<td>±5</td>
<td>±10</td>
<td>±5</td>
<td>±10</td>
</tr>
<tr>
<td>Others</td>
<td>±2</td>
<td>±5</td>
<td>±2</td>
<td>±5</td>
</tr>
</tbody>
</table>

TA — Type Approval or Verification of Declaration.
COP — Conformity of Production.
NA — Not Applicable.

**NOTE** — In case of engines with positive ignition, the tolerance specified manufacturer is acceptable, if the total range of tolerance does not exceed the total range specified above.
ANNEX A  
(Clauses 5.6 and 9)  
RESULTS OF TESTS FOR MEASURING NET ENGINE POWER  

Test Conditions  

Pressures measured at maximum power  
Total barometric pressure, Pa  
Water vapour pressure, Pa  
Exhaust pressure, Pa  

Temperatures Measured at Maximum Power  
of the intake air, K  
at the outlet of the engine intercooler, K  
of the cooling fluid  
at the engine cooling fluid outlet, K'  
at the reference point in the case of air cooling, K'  
of the lubricating oil (indicate point of measurement), K  
of the fuel  
at the fuel pump inlet, K  
in the fuel consumption measuring device, K  

Characteristics of the Dynamometer  
Make  
Model  
Type  

Fuel  
For positive-ignition engines operating on liquid fuel  
Make  
Specification  
Anti-knock additive (lead, etc)  
Type  
Contents, mg/l  
Octane number RON (ASTM D 26 99-70)  
Specific density, g/cu.cm at 288 K  
Lower calorific value, kJ/kg  
For positive-ignition engines operating on gaseous fuel  
Make  
Specification  
Storage pressure, bar  
Utilization pressure, bar  
Lower calorific value, kJ/kg  
For compression-ignition engines operating on gaseous fuels  
Feed system : gas  
Specification of gas used  
Fuel oil/gas proportion
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Lower calorific value

For compression-ignition engines operating on liquid fuel

- **Make**
- Specification of fuel used
- Cetane number (ASTM D 976-71)
- Specific density
- Lower calorific value, kJ/kg

**Lubricant**

- **Make**
- Specification
- SAE Viscosity

**Detailed Results of Measurements**

- Engine speed, min$^{-1}$
- Measured torque, Nm
- Measured power, kW
- Measured fuel flow, g/h
- Barometric pressure, kPa
- Water vapour pressure, kPa
- Inlet air temperature, K
- Power to be added for auxiliaries in excess of Sl No. (i), (ii) and (iii) of Table 1, kW
- Power correction factor
- Corrected brake power, kW (with/without fan$'$)
- Power of fan, kW (to be subtracted if fan not fitted)
- Net power, kW
- Net torque, Nm
- Corrected specific fuel consumption, g/(kWh)$^3$
- Corrected maximum opacity: full load .... %, free acceleration ..... %
- Cooling liquid temperature at outlet, K
- Lubricating oil temperature at measuring point, K
- Air temperature after pressure-charger, K$^4$
- Fuel temperature at injection pump inlet, K
- Air temperature after charge air cooler, K$^4$
- Pressure after pressure-charger, kPa$^4$
- Pressure after charge air cooler, kPa

1) Delete as appropriate.
2) The characteristic curves of the net power and the net torque shall be drawn as a function of the engine speed.
3) Calculated with the net power for compression-ignition and positive-ignition engines, in the latter case multiplied by the power correction factor.
4) Delete where inapplicable.
ANNEX B
(Clause 9)

ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND CONDUCT OF TESTS

B-0 ENGINE

B-0.1 Type

B-0.2 Manufacturer’s name

B-0.3 Working principle (Four/Two-stroke)

B-0.4 Model name (if any)

B-0.5 Type of fuel used

B-0.6 Number and layout of cylinders and firing order

B-0.7 Swept volume

B-0.8 Bore (mm)

B-0.9 Stroke (mm)

B-0.10 Compression ratio (specify tolerance)

B-0.11 Engine performance (declared by the manufacturer and tolerance)

B-0.12 Maximum net power of engine on bench: _______kW at _______rpm (specify standard)

B-1 COMBUSTION

B-1.1 Drawings of combustion chamber and piston crown

B-1.2 Minimum cross-sectional area of ports

B-1.3 Inlet (mm)

B-1.4 Outlet (mm)

B-2 COOLING SYSTEM (LIQUID)

B-2.1 Nature of liquid

B-2.2 Circulating pump Yes/No

B-2.3 Characteristics of circulating pump

B-2.3.1 Make(s)

B-2.3.2 Type(s)

B-2.3.3 Drive ratio

B-2.4 Thermostat setting

B-2.5 Radiator drawing(s)

B-2.5.1 Make(s)

B-2.5.2 Type(s)

B-2.5.3 Relief valve pressure setting
B-2.6 Fan characteristics
B-2.6.1 Make(s)
B-2.6.2 Type(s)
B-2.6.3 Fan drive system
B-2.6.4 Drive ratio
B-2.6.5 Fan cowl

B-3 CHARACTERISTICS OF AIR COOLING SYSTEM

B-3.1 Blower characteristics
B-3.1.1 Make(s)
B-3.1.2 Type(s)
B-3.1.3 Drive ratio(s)
B-3.2 Air ducting (standard production)

B-4 TEMPERATURE REGULATING SYSTEM

B-4.1 Brief description

B-5 TEMPERATURE PERMITTED BY MANUFACTURER

B-5.1 Liquid cooling
B-5.1.1 Maximum temperature at engine outlet
B-5.2 Air cooling
B-5.2.1 Reference Point
B-5.2.2 Maximum temperature at reference point
B-5.3 Maximum exhaust temperature
B-5.3.1 Maximum outlet temperature of the intercooler
B-5.3.2 Maximum exhaust temperature
   [in case of diesel engines, at the point in the exhaust pipe(s) adjacent in outlet flange(s)
    of exhaust manifolds]

B-6 FUEL TEMPERATURE

B-6.1 Minimum
B-6.2 Maximum

B-7 LUBRICANT

B-7.1 Temperature
B-7.1.1 Minimum
B-7.1.2 Maximum
B-7.2 Oil
B-7.2.1 Make
B-7.2.2 Type

B-8 INTAKE SYSTEM

B-8.1 Supercharger Yes/No

B-8.1.1 Description

B-8.1.2 Make(s)

B-8.1.3 Type(s)

B-8.2 Intake manifold

B-8.2.1 Description

B-8.3 Air filter

B-8.3.1 Make

B-8.3.2 Type

B-8.4 Description and diagrams of inlet pipe and their accessories (dash pot, heating device, additional air intake, etc)

B-9 FUEL FEED (BY CARBURETTOR)

B-9.1 Number

B-9.2 Make

B-9.3 Type

B-9.4 Adjustments (specify tolerance)

B-9.4.1 Jets

B-9.4.2 Venturie(s)

B-9.4.3 Float-chamber level

B-9.4.4 Mass of float

B-9.4.5 Float needle

B-9.5 Dimensions of mixture duct

B-9.6 Manual/Automatic choke closure setting

B-9.7 Feed pump

B-9.7.1 Pressure (specify the tolerance) or characteristic diagrams

B-9.7.2 Type of fuel feed pump

B-10 FUEL FEED (BY FUEL INJECTION)

B-10.1 Injection system description
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B-10.2 Working principle: intake manifold/direct injection/injection pre-chamber/swirl chamber

B-10.3 Fuel pump

B-10.3.1 Make(s)

B-10.3.2 Type(s)

B-10.4 Delivery mm/per stroke at pump rpm (specify the tolerance) or characteristic diagram (specify the tolerance)

B-10.5 Calibration procedure on engine/pump bench

B-10.6 Injection timing

B-10.7 Injection advance curve

B-10.8 Injection advance (specify the tolerance)

B-10.9 Injectors

B-10.9.1 Type

B-10.9.2 Make

B-10.9.3 Opening pressure (specify the tolerance) or characteristic diagram

B-11 DEVICE FOR RECYCLING CRANK-CASE GASES

B-11.1 Description and diagrams

B-12 GOVERNOR

B-12.1 Make(s)

B-12.2 Type(s)

B-12.3 Cut off point under load

B-12.4 Maximum speed without load

B-12.5 Idle speed

B-13 COLD START DEVICE

B-13.1 Make(s)

B-13.2 Type(s)

B-13.3 System description

B-14 STARTING AID

B-14.1 Make(s)

B-14.2 Type(s)
B-14.3 System description

B-15 VALVE TIMING OR EQUIVALENT DATA

B-15.1 Maximum lift of valves
B-15.1.1 Inlet (mm)
B-15.1.2 Exhaust (mm)
B-15.2 Angle of valves (w.r.t. top dead center)
B-15.3 Inlet
B-15.3.1 Opening
B-15.3.2 Closing
B-15.4 Exhaust
B-15.4.1 Opening
B-15.4.2 Closing
B-15.5 Reference or Setting ranges
B-15.6 Valve gap
B-15.7 Distribution by ports
B-15.7.1 Volume of crank-case cavity with piston at TDC
B-15.7.2 Description of reed valve, if any with drawing
B-15.7.3 Description (with drawing) of inlet ports, scavenging and exhaust ports with corresponding timing. (The drawing should include one representing the inner surface of the cylinder.)

B-16 IGNITION SYSTEM

B-16.1 Make
B-16.2 Type
B-16.3 Ignition advance curve (specify the tolerance)
B-16.4 Ignition timing (specify the tolerance)
B-16.5 Contact point gap and dwell angle (specify the tolerance)

B-17 EXHAUST SYSTEM

B-17.1 Description and diagrams

B-18 LUBRICATION SYSTEM

B-18.1 Description of system
B-18.2 Lubrication oil capacity
B-18.3 Position of lubricant reservoir
B-18.4 Feed system (pump, injection in to intake mixing with fuel, etc)
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B-18.5 Lubricating pump

B-18.5.1 Make

B-18.5.2 Type

B-18.6 Mixture with fuel: Yes/No

B-18.6.1 Percentage

B-18.7 Oil cooler: Yes/No

B-18.7.1 Drawings/Makes and types

B-19 ELECTRICAL EQUIPMENT

B-19.1 Generator/Alternator characteristics (specify the tolerance)

B-19.1.1 Make

B-19.1.2 Type

B-20 OTHER ENGINE DRIVEN AUXILIARIES

B-20.1 Enumeration and brief description, if necessary

B-21 ADDITIONAL INFORMATION ON TEST CONDITIONS

B-21.1 Sparking plugs

B-21.1.1 Make

B-21.1.2 Type

B-21.1.3 Spark-gap setting

B-21.2 Ignition coil

B-21.2.1 Make

B-21.2.2 Type

B-21.3 Ignition condenser

B-21.3.1 Make

B-21.3.2 Type

B-21.4 Radio interference suppression equipment

B-21.4.1 Make

B-21.4.2 Type

B-22 IDLING SYSTEM

B-22.1 Idling speed (rpm) (specify the tolerance)

B-22.2 Description of settings and relevant requirements

B-22.3 Carbon monoxide content by volume in the exhaust gas with the engine idling, percent (manufacturer’s standard)
B-23 ADDITIONAL REQUIREMENTS FOR VEHICLES TO BE TESTED ON CHASSIS DYNAMOMETER

B-23.0 Name of model and variants
B-23.1 Maximum acceleration
B-23.2 Gear shifting pattern
B-23.3 Maximum speed, km/h
B-23.4 Vehicle kerb weight, kg
B-23.5 Front axle
B-23.6 Rear axle
B-23.7 Reference mass
B-23.8 Type of transmission (Manual/Automatic/Semi-automatic)
   (NOTE — If automatic give all pertinent data)
B-23.9 Clutch type (Wet/Dry/Single plate/Multiplate/Hydraulic)
B-23.10 Gear box
B-23.10.1 Type
B-23.10.2 Model name (if any)
B-23.10.3 Gear shifting control system
B-23.10.4 Number of gears
B-23.10.5 Stall ratio of torque converter
B-23.10.6 Sub-transmission
B-23.10.7 Type
B-23.10.8 Control system
B-23.10.9 Gear ratio
   High
   Low
B-23.10.10 Final drive (Crown wheel)
B-23.10.11 Type
B-23.10.12 Reduction ratio
B-23.10.13 Differential type
B-23.10.14 Final drive ratio
B-23.10.15 Gear ratio

<table>
<thead>
<tr>
<th>Gear-Box Ratio</th>
<th>Over Ratio</th>
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</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td></td>
</tr>
<tr>
<td>5th</td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td></td>
</tr>
<tr>
<td>Over drive</td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td></td>
</tr>
</tbody>
</table>
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B-23.11 Number of axles
- Driven
- Non-driven

B-24 ADDITIONAL REQUIREMENTS FOR COMPRESSION IGNITION ENGINES

B-24.1 Maximum permitted depression of air intake at characteristic place (specify location of measurement)
B-24.2 Exhaust back pressure at maximum net power and location of measurement (kPa)
B-24.3 Effective volume of exhaust (specify the tolerance range)
B-24.4 Moment of inertia of combined flywheel and transmission at condition when no gear is engaged
B-24.5 Injection piping
B-24.5.1 Length (mm)
B-24.5.2 Internal diameter (mm)
B-24.6 Maximum rated speed (specify the tolerance)
B-24.7 Minimum rated speed (specify the tolerance)
B-24.8 Power absorbed by fan, kW (specify the tolerance)
B-24.9 Maximum net torque on bench Nm at rpm
B-24.10 Declared speed and powers of the engine/vehicle¹ submitted for type approval (Speeds to be agreed with the testing agency)

<table>
<thead>
<tr>
<th>Measurement Point</th>
<th>Engine Speed, rpm</th>
<th>Power, kW</th>
<th>Vehicle Speed and Gear Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B-25 ADDITIONAL POLLUTION CONTROL DEVICES (IF ANY AND IF NOT COVERED BY ANOTHER HEADING)

B-25.1 Catalyser make
B-25.2 Identification mark
B-25.3 Type of catalytic action (one/two/three way)
B-25.4 Total charge of precious metal (g/vehicle)
B-25.5 Relative concentration
B-25.5.1 Platinum
B-25.5.2 Rhodium
B-25.6 Substrate (monolythic metal/ceramic/honeycombs)
B-25.7 Cell density (cells per square inch)
B-25.8 Type of casing for catalyser
B-25.9 Diagram indicating the arrangement

¹) Strike out whichever is not applicable.
### ANNEX C

(Foreword)

**COMMITTEE COMPOSITION**

Automotive Primemovers Sectional Committee, TED 2

**Chairman**

Dr. M. L. Mathur  
Alok Villa, 17, Sector 'A',  
Shastri Nagar, Jodhpur 342003

<table>
<thead>
<tr>
<th>Members</th>
<th>Representing</th>
</tr>
</thead>
</table>
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(Continued from page 22)

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Kinetic Engg Ltd, Pune
Kirluskar Oil Engines Ltd, Pune
Mahindra and Mahindra Ltd, Nasik
Maruti Udyog Ltd, Gurgaon
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This Indian Standard has been developed from Doc : No. TED 2 (226).

Amendments Issued Since Publication

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