

Engine Test Code – Spark Ignition and Diesel – SAE J816b

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NOTICE: When reaffirmation, amendment, revision, or cancellation of this standard is initially proposed, the industry group responsible for this standard shall inform the military coordinating activity of the proposed change and request participation.

Custodians:
Army - AT
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[This new standard test code has been adopted by SAE to supersede the former SAE Engine Test Code—Nonturbocharged Spark Ignition and Diesel. The new standard has evolved from that code and from the following former SAE documents: SAE Gasoline Engine Test Code adopted in 1917, SAE Diesel Engine Test Code adopted in 1931, and the 1963 publication designated as SAE J606 which referenced these two codes as one publication.]

The purpose of this code is to provide a standard procedure covering laboratory dynamometer test methods for determining performance characteristics of diesel and spark ignition engines. It is applicable to four-stroke and two-stroke cycle diesel engines, naturally aspirated, mechanically supercharged or turbocharged, with or without charge air cooling. It is also applicable to all types of spark ignition engines except turbocharged spark ignition engines on which definitive power correction data are lacking. It is not intended as a laboratory manual or a method for establishing rated power or for derating engines for altitude.

This code is composed of the following Sections:

1. Definitions of Terminology
2. Test Equipment Requirements
3. Test Procedures
4. Computations
5. Presentation of Results

1. Definitions of Terminology

1.1 **Power Output**—Engine power output shall be¹ expressed in units of “horsepower,” equivalent to 550 ft-lb/s or “kilowatts” equivalent to 1000 J/s.

1.1.1 **OBSERVED POWER** is the power actually developed by an engine under the atmospheric conditions existing during the test.

1.1.2 **CORRECTED POWER** is the observed power adjusted to standard atmospheric conditions, using the correction methods specified in paragraph 4.

1.2 Gross and Net Power

1.2.1 **GROSS POWER** is the power output of a “basic” engine as defined in paragraph 1.6.

1.2.2 **NET POWER** is the power output of a “fully equipped” engine as defined in paragraph 1.6.

1.3 **Brake Power**—Brake power is the power available at the output member(s) for doing useful work.

1.3.1 **MAXIMUM BRAKE POWER**² is the highest power developed at a given speed.

1.3.2 **PEAK BRAKE POWER**² is the highest power developed within the engine speed range.

1.3.3 **PEAK POWER ENGINE SPEED** is the speed at which peak power occurs. If peak power speed cannot be read easily due to flatness of the power curve, it may be approximated as the average of the two engine speeds at which power is 98% of its highest value.

1.3.4 **INTERMITTENT BRAKE POWER** is the highest power recommended by the manufacturer for satisfactory operation within the manufacturer's specified conditions of load, speed, and duty cycle.

1.3.5 **CONTINUOUS BRAKE POWER** is the power recommended by the manufacturer for satisfactory operation under the manufacturer's specified continuous duty conditions.

1.3.6 **RATED BRAKE POWER** is the power specified by the manufacturer for a given application at a given (rated) speed. (See paragraph 5.)

1.4 **Friction Power**—Friction power is the power required to drive the engine as equipped during the power test. Friction may be approximated by one of the following methods with sufficient accuracy for the purposes of this code:

- (a) Hot motoring method (preferred method, see paragraph 3.6.1.2).
- (b) Calculated friction using mechanical efficiency equations or tables. (See paragraphs 4.5.2.2 and 4.5.3.2.)

1.5 **Indicated Power**—Indicated power is the power developed in the cylinders. For the purpose of this case, it is defined as the sum of the brake power and the friction power.

1.6 Engine

1.6.1 **BASIC ENGINE** is an engine equipped only with the built-in accessories essential to its operation: fuel pump, oil pump, coolant pump, and built-in emission control equipment. A generator or alternator is to be included only if some accessories (such as a fuel pump) are electrically driven.

1.6.2 **FULLY EQUIPPED ENGINE** is an engine equipped with all the accessories necessary to perform its intended functions unaided. This includes, but is not restricted to, the basic engine of paragraph 1.6.1 plus intake air system, exhaust system, cooling system, generator or alternator, starter, and emission control equipment.

2. **Test Equipment Requirements**—The required limits of accuracy concern the instrument precision specified by the manufacturer of the instruments used and do not include human or other probable errors involved in the reading.

2.1 Torque

2.1.1 **Dynamometer** and scale capacity shall be compatible with engine size. Dynamometer shall be capable of maintaining load and speed conditions as defined in paragraph 3.

2.1.2 **Dynamometer coupling drive** between engine and dynamometer shall be suitable for operation through the test engine speed range with minimum power loss or out-of-balance.

2.1.3 DYNAMOMETER BALANCE, CALIBRATION, AND SENSITIVITY

2.1.3.1 Scales shall be checked for zero scale reading with the dynamometer frame in the neutral position.

2.1.3.2 Calibration of the dynamometer with the engine running at some fixed beam load, for example, 100 lb (445 N), may be checked by the addition of a 100 lb (445 N) weight to the opposite side, which should bring the scale back to zero. This shall be done for several different loads within the range of expected operation and shall be repeated under static conditions. The result thus obtained shall be accurate within $\pm 1/2\%$ of the observed full load reading.

2.1.3.3 Sensitivity of the dynamometer and scales shall be checked by adding small increments of weight until the pointer moves a readable amount. The magnitude of this weight, which is the sensitivity, shall not exceed $1/4\%$ of the observed full load reading. Several points shall be checked within the operating range.

2.2 Speed

2.2.1 Revolution counter shall be accurate within $\pm 1/4\%$ of the observed reading or ± 10 revolutions, whichever is less.

2.2.2 Tachometer shall be accurate within $\pm 1/2\%$ of the observed value if the reading is used for computations.

2.3 **Time**—The time measuring instruments shall be accurate within $\pm 1/4\%$ of the observed reading.

2.4 Fuel System

2.4.1 The engine fuel system used in the test shall be in accordance with the manufacturer's specifications.

2.4.2 Fuel consumption measurement (mass or volume) instrumentation shall be accurate within $\pm 1\%$ of the observed reading.

2.5 Temperatures

2.5.1 Temperatures shall be measured in degrees Fahrenheit using English units or degrees Celsius using metric units.

2.5.2 Accuracy of instrumentation for measuring temperatures of 400°F (204°C) or less should be $\pm 2^\circ\text{F}$ ($\pm 1^\circ\text{C}$), and at temperatures above 400°F (204°C) should be $\pm 10^\circ\text{F}$ ($\pm 5^\circ\text{C}$).

2.5.3 The necessary temperature measurements and corresponding locations are as follows:

2.5.3.1 Temperature of the inlet air to the engine (ambient air) shall be measured in a manner to get a mass average temperature. The temperature shall be taken in the engine inlet air stream or within 6 in. (152 mm) of the air inlet horn or air cleaner. Care should be taken to shield the thermometer or thermocouple from radiant heat sources, and a sufficient number of locations shall be checked to assure a representative average inlet temperature.

2.5.3.2 **Coolant Temperatures**—Temperatures in liquid-cooled engines shall be measured at the inlet and outlet of the engine. Temperatures in air-cooled engines should be measured at point(s) specified by the manufacturer, such as spark plug(s) and cylinder head fin(s).

2.5.3.3 Oil temperatures shall be measured in the oil gallery.

2.5.3.4 Fuel temperature shall be measured at the outlet of the volumetric fuel measuring device if used. Fuel supply temperature should be measured at the outlet of the primary filter for fuel injected engines and at the carburetor for carbureted engines.

¹Any specified condition or action preceded by “shall be” is a requirement of this code; if preceded by “should be,” it is recommended but not required.

²Maximum and peak brake power are outside the usual operating range of commercial diesel engines.

2.6 Pressures

2.6.1 Pressures shall be measured in pounds per square inch, inches of mercury, or inches of water (pascals), either above or below atmospheric pressure.

2.6.2 The necessary pressure measurements, the required instrument accuracies, and corresponding locations are as follows:

2.6.2.1 Air cleaner and piping restriction ± 0.1 in. water (± 25 Pa).

2.6.2.2 Exhaust pressure measured within 6 in. (152 mm) downstream of the outlet of the engine exhaust system specified for the test ± 0.1 in. Hg or ± 338 Pa. (See paragraphs 3.6.1.1 and 3.6.2.1.)

2.7 Atmospheric Conditions

2.7.1 All measurements shall be made in a location representative of the engine's test environment.

2.7.2 Barometric pressure: aneroid or mercury barometer corrected for temperature (accuracy ± 0.02 in. Hg or ± 68 Pa).

2.7.3 Wet and dry bulb temperatures shall be measured with a sling-psychrometer or equivalent. The thermometers used shall be accurate within $\pm 0.5^\circ\text{F}$ or $\pm 0.3^\circ\text{C}$.

2.8 Exhaust Smoke—Diesel Engines—SAE J255 should be used to guide smoke testing. The U. S. Public Health Service smoke measuring instrumentation and procedures are currently generally accepted and should be followed for engine smoke evaluation, especially when engine transients are to be considered.³

Since these procedures will be updated and added to over a period of time, the current SAE Handbook should be consulted for proper diesel engine exhaust smoke testing when tests are to be run.

2.9 Engine Emissions—SAE Recommended Practices and Information Reports on measurement of engine emissions are available to guide these tests. A current list is as follows:

SAE J170, Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks.

SAE J171, Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks Using the Enclosure Technique.

SAE J177, Measurement of Carbon Dioxide, Carbon Monoxide, and Oxides of Nitrogen in Diesel Exhaust.

SAE J215, Continuous Hydrocarbon Analysis of Diesel Exhaust.

SAE J244, Measurement of Intake or Exhaust Flow in Diesel Engines.

SAE J900, Crankcase Emission Control Test Code.

SAE J989, Carbon Monoxide Concentration Test Procedure.

Since these procedures will be updated and added to over a period of time, the current SAE Handbook should be consulted for proper engine emissions testing when tests are to be run.

3. Test Procedures—This section contains the required test procedures for determining the following engine performance characteristics: gross power, net power, and part throttle fuel consumption.

3.1 Description of Tests

3.1.1 Gross brake power test consists of a run at full throttle to determine power output versus speed of the basic engine as defined in paragraph 1.6.

3.1.2 Net brake power test consists of a run at full throttle to determine power output versus speed of the fully equipped engine as defined in paragraph 1.6.

3.1.3 Part throttle fuel consumption test consists of a series of runs at various speeds to determine the fuel consumption at specified percentages of the observed brake power at full throttle.

3.2 Engine Installation and Adjustments—The test engine shall be a representative unit within the manufacturer's specifications. All auxiliary equipment used on the test engine such as fan, air cleaner, muffler, and pumps shall be listed and described.

Spark ignition carbureted engines should be mounted on the dynamometer stand at the installation angle specified for their application. If engine exhaust is connected to a laboratory exhaust system, that system shall not cause a back pressure exceeding the value specified by the manufacturer or a vacuum of more than 3 in. (76 mm) of water. If the engine air inlet is connected to a laboratory air system, the system should neither supply air to the engine above atmospheric pressure nor at a vacuum exceeding that specified by the manufacturer.

The generator (alternator) shall be disconnected if an external power source is used for ignition and/or starting unless certain accessories such as the fuel pump or coolant fan are electrically driven, in which case the generator or alternator shall operate at a load sufficient to power them. On spark ignition

engines, the intake manifold heat control shall be secured in the "off" position for the full throttle tests.

Adjustments shall be made before the test in accordance with the manufacturer's instructions. No changes or adjustments shall be made during the test except as indicated in the test procedure.

3.3 Run-In—The engine shall be run-in according to the manufacturer's recommendations. If no such recommendation is available, the engine shall be run-in until power and fuel consumption are repeatable within 1% over a 4 h period.

3.4 Fuels and Lubricants

3.4.1 Fuel used shall conform to the manufacturer's specifications:

3.4.1.1 Spark Ignition Engines

(a) Record Research and Motor octane number and API gravity of liquid fuel.

(b) Record lower heat value (LHV) in Btu/ft³ (kJ/m³) at 60°F (16°C) and 29.92 in. Hg (101 kPa), and composition of gaseous fuels.

3.4.1.2 Diesel Engines—Record ASTM or other fuel specification and Cetane No., API gravity, kinematic viscosity in centistokes (m²/s) at 100°F (37.8°C), and distillation in °F (°C) at 10%, 50%, 90%, and end point.⁴

3.4.2 Lubricating oil used shall conform with the manufacturer's recommendations. Record oil performance level and SAE viscosity number of the lubricant.

3.5 Test Conditions—Performance data shall be obtained under stabilized normal operating conditions, with an adequate fresh air supply to the engine. Combustion chambers of spark ignition engines shall be free of deposits. Test conditions, such as inlet air temperature, should be selected as near to standard as possible (paragraph 4.3) in order to minimize the magnitude of the correction factor.

3.5.1 No data shall be taken until torque, speed, and temperatures have been maintained within 1% for at least 2 min.

3.5.2 Engine speed should be held as nearly constant as possible during a run or reading and shall not deviate from the nominal speed by more than $\pm 1\%$ or ± 10 rpm, whichever is greater.

3.5.3 Observed brake load and fuel consumption data shall be taken simultaneously and shall be the average of two stabilized sustained values which do not vary more than 1%. A measuring interval of not less than 30 s shall be used when measuring speed and fuel consumption with an automatically synchronized counter timer combination; for hand operation, the time interval shall be not less than 120 s.

3.5.4 Coolant outlet temperature in liquid-cooled engines shall be controlled at $190 \pm 10^\circ\text{F}$ ($88 \pm 5^\circ\text{C}$) unless otherwise specified by the manufacturer.

3.5.5 Fuel temperature at the inlet of the diesel engine fuel pump shall be controlled to $100 \pm 10^\circ\text{F}$ ($37.8 \pm 5^\circ\text{C}$).

3.6 Procedures

3.6.1 GROSS POWER TEST

3.6.1.1 *Engine Equipment and Settings*—A basic engine is used for this test (see paragraph 1.6).

Air cleaner—shall be on a used system with equivalent restriction

Air preheat—optional

Radiator—off

Fan—off } Liquid-cooled

Fan or blower on, with air control mechanism operating normally—

Air-cooled

Muffler, exhaust pipe and tail pipe—off

Heat valve—warmed up positions

Timing—normal

Spark advance—normal

Fuel pump setting—normal

Carburetor setting—normal

Emission controls integral with engine—normal

3.6.1.2 *Procedure*—Record data for at least five approximately evenly spaced operating speeds to define completely the power curve between 600 rpm (or the lowest stable speed) and the maximum engine speed recommended by the manufacturer.

On spark ignition engines and on diesel engines where motoring friction is to be used, the measurement shall be taken with coolant inlet and oil gallery temperatures within 5°F (3°C) of those observed during the power test.

3.6.1.3 *Data to be Recorded for Test Documentation*—See paragraph 5.

Speed

Torque or beam load (power, friction if measured)

³If the U. S. Public Health Service Smokemeter is used, the Federal Register, Vol. 33, No. 108 dated June 4, 1968, Part II, shall guide its use. Paragraphs 85.124, 85.125, and 85.126 are applicable.

⁴Kinematic viscosity at standard temperatures other than 37.8°C , such as 20 or 50°C , may be used.