

**Procedure for Measuring Basic  
Highway Vehicle Engine Performance  
and Fuel Consumption—Spark  
Ignition and Diesel  
—SAE J1312 JUN80**

SAE Recommended Practice  
Approved June 1980

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# PROCEDURE FOR MEASURING BASIC HIGHWAY VEHICLE ENGINE PERFORMANCE AND FUEL CONSUMPTION—SPARK IGNITION AND DIESEL—SAE J1312 JUN80

## SAE Recommended Practice

Report of the SAE/DOT Advisory Committee, approved June 1980.

**Scope**—This procedure is specifically designed to determine a fuel rate versus torque map for heavy-duty spark ignition and diesel engines as determined at the DOT/SAE Truck & Bus Fuel Economy Measurement Conference April 21–23, 1975. This engine performance map, when combined with accessory losses, transmission and driveline losses, vehicle aerodynamics, etc., can be used with vehicle operating profiles in a computer program to simulate vehicle fuel economy.

Use of this procedure results in torque and fuel rate being measured at 30 data points, minimum, and friction torque, either measured or calculated, at five data points, minimum. Testing is accomplished using a procedure very similar to SAE J816b, but actually is quite different since this is a specific test for a specific purpose rather than a general test code as specified in J816b. It is recommended that the test be run at inlet air temperatures as near as possible to the standard specified in J816b so as to minimize correction. If correction of full load torque is required, it is done according to J816b.

The results of a test conducted according to this procedure are plotted as a fuel rate versus torque map for as many speeds as required to define the operating characteristics of the engine tested.

**Purpose**—The purpose of this recommended practice is to provide a standard procedure covering laboratory dynamometer test methods for determining performance characteristics (torque) and fuel consumption (rate) of the diesel and spark ignition engines used in highway vehicles. 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. This procedure will allow the development of a fuel rate map which can be logically related to vehicle fuel consumption simulation procedures. These maps by themselves cannot be used to determine vehicle fuel consumption on an overall, accurate basis, but they are intended to be used to supply the input to a computer simulation along with the proper vehicle configurations and operating profiles.

This recommended practice 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 **Brake Torque**—The brake torque is the torque available at the output shaft(s) for doing useful work.

1.2 **Friction Torque**—The friction torque is the torque required to drive the basic engine.

1.3 **Rated Speed**—The speed selected by the manufacturer for rating purposes.

1.4 **Peak Torque Speed**—The speed selected by the manufacturer at which maximum torque occurs.

1.5 **Basic Engine**—Engine equipped only with the built-in accessories essential to its operation: fuel pump, oil pump, coolant pump, and built-in emission control equipment. An unloaded generator or alternator can be included.

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

#### 2.1 Torque

2.1.1 **Dynamometer capacity** shall be<sup>1</sup> compatible with engine size. Dynamometer shall be capable of maintaining load and speed conditions as defined in Section 3.

2.1.2 **Dynamometer coupling** between engine and dynamometer shall be suitable for operation through the test engine speed range with respect to out-of-balance or elastic properties creating undesirable resonance.

#### 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 indicator 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  $\pm 10$  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 S. I. units.

2.5.2 **Accuracy of instrumentation** for measuring temperatures of  $400^\circ\text{F}$  ( $204^\circ\text{C}$ ) or less should be  $\pm 2^\circ\text{F}$  ( $\pm 1^\circ\text{C}$ ), and at temperatures above  $400^\circ\text{F}$  ( $204^\circ\text{C}$ ) 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 **Inlet Air Temperature**—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**—Temperatures shall be measured in the oil gallery unless otherwise specified by the engine manufacturer.

2.5.3.4 **Fuel Temperature**—Fuel supply temperature should be measured at the inlet side of the engine fuel pump for fuel injected engines and at the carburetor for carbureted engines.

#### 2.6 Pressures

2.6.1 **Pressures** shall be measured in pounds per square inch, inches of mercury, inches of water, or kilopascals, 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**  $\pm 0.1$  in water ( $\pm 0.025$  kPa).

2.6.2.2 **Exhaust back pressure** measured within 6 in (152 mm) downstream of the outlet of the engine exhaust system specified for the test (except: no closer than 12 in (305 mm) from the turbocharger outlet)  $\pm 0.1$  in Hg or  $\pm 0.338$  kPa. (See paragraph 3.5.1.)

#### 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  $\pm 0.02$  in Hg or  $\pm 0.068$  kPa).

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  $\pm 0.3^\circ\text{C}$ .

3. **Test Procedure**—This section contains the required test procedures for determining the following engine performance characteristics: brake torque, friction torque, part load fuel consumption, and full load fuel consumption.

3.1 **Engine Installation and Adjustments**—The test engine shall be a

<sup>1</sup>Any 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.

representative unit within the manufacturer's specifications.

Spark-ignition carbureted engines should be mounted on the dynamometer stand at the installation angle specified for their application. For engine equipment and setting, see paragraph 3.5.1.

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 on the test procedure.

**3.2 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, or a minimum of 18 h run-in.

### 3.3 Fuels, Lubricants, and Coolant

**3.3.1** Fuel used shall conform to the EPA specifications for emission durability testing.

#### 3.3.1.1 Spark Ignition Engines

**3.3.1.1.1** Record research and motor octane number and API gravity of liquid fuel.

**3.3.1.1.2** Record lower heat value (LHV) in Btu/ft<sup>3</sup> (kJ/m<sup>3</sup>) at 60° F (16° C) and 29.92 in Hg (101 kPa) of gaseous fuels.

**3.3.1.2 Diesel Engines**—Record ASTM or other fuel specification and Cetane No. API gravity, kinematic viscosity in centistokes (m<sup>2</sup>/s) at 100° F (37.8° C), and distillation in ° F (° C) at 10%, 50%, 90%, and end point.<sup>2</sup>

**3.3.2** Lubricating oil used shall conform with the manufacturer's recommendations. Record engine oil performance and service classification designation, SAE Viscosity Number, and manufacturer.

**3.3.3** Coolant used shall be only water or water treated with commercially available corrosion inhibitors and/or lubricants in the amounts recommended by the engine manufacturer.

**3.4 Test Conditions**—Performance data shall be obtained under stabilized normal operating conditions with an adequate fresh air supply to the engine. 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.

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

**3.4.2** 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 ±1% or ±10 rpm, whichever is greater.

**3.4.3** Observed 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%.

**3.4.4** Coolant outlet temperature in liquid-cooled engines shall be controlled at 190 ± 10° F (88 ± 5° C) unless otherwise specified by the manufacturer.

**3.4.5** Fuel temperature should be controlled to 100 ± 10° F (37.8 ± 5° C).

**3.4.6** Inlet air temperature should be selected as near to standard as possible. For engines used in conjunction with systems designed to either add or remove heat from the intake charge (such as, aftercoolers, stoves, etc.), the heating or cooling systems shall be operational in a manner similar to the way in which they function in the vehicle.

### 3.5 Test for Fuel Rate Versus Torque

**3.5.1 Engine Equipment and Settings**—A basic engine is used for this test (see paragraph 1.5).

(a) Air preheat—optional.

(b) Radiator—off.

(c) Fan—off.

(d) Fan or blower on, with air control mechanism operating normally for air-cooled engines.

(e) Muffler, exhaust pipe and tail pipe—off.

(f) Heat valve—warmed up positions.

(g) Timing—normal.

(h) Spark advance—normal.

(i) Fuel pump setting—normal.

(j) Carburetor setting—normal.

(k) Emission controls integral with engine—normal.

(l) Inlet and exhaust restriction shall be controlled.

(m) Set manufacturer's recommended maximum inlet restriction for clean air cleaner and maximum exhaust restriction at full load and rated speed. The exhaust back pressure shall not be less than atmospheric pressure and the inlet air pressure shall not be allowed to exceed atmospheric pressure during any portion of the test.

**3.5.2 Procedure**—The following procedure is recommended for determining a minimum number of speeds and loads for the development of a fuel rate versus torque map (see Section 5).

**3.5.2.1** Subtract the peak torque speed from the rated speed and divide by three to determine the width of the steps in speed to be used.

**3.5.2.2** The engine shall be tested at 0, 20, 40, 60, 80, and 100% of maximum load at each of five equally spaced speeds between rated and a point which is four steps (as determined above) lower than rated speed. In determining the speed points, the calculated values may be rounded to the nearest 100 rpm.

Additional points shall be run as necessary to define the shape of the droop curve or to adequately cover the modes of operation encountered. These points shall include maximum governed speed (0% load) and minimum governed speed (0% load). Idle fuel rate and engine speed shall also be measured and recorded.

**3.5.2.3** Friction torque at the speeds established should be determined by the hot motoring method. The measurement shall be taken with coolant inlet and oil temperatures within 5° F (3° C) of those observed at each maximum load condition.

### 3.5.3 Data to be Recorded for Test Documentation (See Fig. 1)

- Speed.
- Torque or beam load.
- Ambient air temperature, pressure, humidity.
- Fuel consumption rate.
- Exhaust back pressure (see paragraph 2.6.2.2).
- Fuel supply temperature.
- Inlet air pressure (if connected to laboratory system).
- Oil and coolant temperature.

The following data should also be recorded where applicable and for safety of operation:

- Oil pressure.
- Intake manifold temperature.
- Exhaust temperature.
- Air cleaner and piping restriction.
- Ignition or injection timing.
- Fuel supply pressure.

| Required Data                         |           | Units                     |
|---------------------------------------|-----------|---------------------------|
| 1. Speed                              |           | rpm                       |
| 2. Torque                             | Torque    | ft-lb (N-m)               |
|                                       | Beam Load | lb (N)                    |
| (Friction torque if measured)         | Torque    | ft-lb (N-m)               |
|                                       | Beam Load | lb (N)                    |
| 3. Ambient Air Temperature            |           | ° F (° C)                 |
| 4. Ambient Air Pressure               |           | in Hg (kPa)               |
| 5. Ambient Air Humidity               |           | % (%)                     |
| 6. Fuel Consumption (Liquid)          |           | lb/h (kg/h)               |
| 7. Exhaust Back Pressure              |           | in Hg (kPa)               |
| 8. Fuel Supply Temperature            |           | ° F (° C)                 |
| 9. Air Inlet Restriction              |           | in H <sub>2</sub> O (kPa) |
| 10. Oil Temperature                   |           | ° F (° C)                 |
| 11. Coolant Temperature               |           | ° F (° C)                 |
| Optional Data (As Applicable)         |           |                           |
| 1. Oil Pressure                       |           | lb/in <sup>2</sup> (kPa)  |
| 2. Intake Manifold Temperature        |           | ° F (° C)                 |
| 3. Exhaust Temperature                |           | ° F (° C)                 |
| 4. Air Cleaner and Piping Restriction |           | in H <sub>2</sub> O (kPa) |
| 5. Ignition or Injector Timing        |           | deg (crankshaft)          |
| 6. Fuel Supply Pressure               |           | lb/in <sup>2</sup> (kPa)  |

FIG. 1—TEST DATA RECORD

<sup>2</sup>Kinematic viscosity at standard temperatures other than 37.8° C, such as 20 or 50° C may be used.

#### 4. Computations

##### 4.1 Definition of Symbols

| Symbol                                 | Definition                         | Units              |                   |
|----------------------------------------|------------------------------------|--------------------|-------------------|
|                                        |                                    | English            | SI                |
| B                                      | Barometric pressure                | in Hg              | kPa               |
| F                                      | Fuel consumption (liquid)          | lb/h               | kg/h              |
| L                                      | Dynamometer scale reading          | lb                 | N                 |
| M                                      | Time of fuel measurement           | min                | min               |
| N                                      | Engine speed                       | rpm                | rpm               |
| R                                      | Dynamometer torque arm             | ft                 | m                 |
| T                                      | Torque                             | lb-ft              | N·m               |
| W                                      | Mass of fuel                       | lb                 | kg                |
| d                                      | Air density                        | lb/ft <sup>3</sup> | kg/m <sup>3</sup> |
| e                                      | Water vapor pressure in atmosphere | in Hg              | kPa               |
| n                                      | Mechanical efficiency              | %                  | %                 |
| t                                      | Ambient temperature                | °F                 | °C                |
| <b>Subscripts</b>                      |                                    |                    |                   |
| d                                      | Dry air condition                  |                    |                   |
| t                                      | Observed at test conditions        |                    |                   |
| f                                      | Friction                           |                    |                   |
| b                                      | Brake                              |                    |                   |
| <b>Superscripts*</b>                   |                                    |                    |                   |
| To denote standard ambient conditions. |                                    |                    |                   |

#### 4.2 Useful Equivalents

$$\begin{aligned}
 1 \text{ kg} &= 2.2056 \text{ lb mass} \\
 1 \text{ N} &= 0.2248 \text{ lb force} \\
 1 \text{ kPa} &= 0.1450 \text{ lb/in}^2
 \end{aligned}$$

#### 4.3 Standard Ambient Conditions

|                         |                  |                                                      |
|-------------------------|------------------|------------------------------------------------------|
| Barometric pressure     | B*               | 29.38 in Hg (99 kPa)                                 |
| Temperature             | T*               | 85°F (29.4°C)                                        |
| Vapor pressure          | e*               | 0.38 in Hg (1.3 kPa)                                 |
| Dry barometric pressure | B <sub>d</sub> * | 29.00 in Hg (97.9 kPa)                               |
| Dry air density         | d <sub>d</sub> * | 0.0705 lb/ft <sup>3</sup> (1.124 kg/m <sup>3</sup> ) |

#### 4.4 Computations From Test Data

##### 4.4.1 Observed Brake Torque

$$\text{Brake torque, } T_b = (L \cdot R)_t$$

4.4.2 Friction Torque—Engine friction for purposes of this recommended practice may be established by one of the following methods:

##### 4.4.2.1 Observed Friction Torque (Hot Motoring Method):

$$\text{Friction torque, } T_f = (L \cdot R)_t$$

4.4.2.2 Calculated Friction Torque—The mechanical efficiency can be determined by using equations or tables (see paragraphs 4.5.2.2 and 4.5.3.2 of SAE J816b). Friction torque may be calculated as follows:

$$T_f = T_b \left( \frac{100}{n} - 1 \right)$$

##### 4.4.3 Fuel Consumption (Rate)

$$F_t = W_t \cdot \frac{60}{M}$$

##### 4.4.4 Barometric Pressure

$$\text{Dry barometric pressure, } B_d = B - e$$

#### 4.5 Corrected Torque

4.5.1 Correction Factor—The performance of diesel and spark ignition engines is affected by barometric pressure, temperature, and humidity of the ambient atmosphere. Therefore, in order to provide a common basis for comparison, it is necessary to apply a correction factor to convert the observed data to specified standard atmospheric conditions. The method of correction is prescribed in SAE J816b.

5. **Presentation of Results**—Data obtained in paragraph 3.5.2.2 shall be reported on the form of a fuel rate (lb/h) versus torque map. See Fig. 2. Data is to be corrected in accordance with SAE J816 and noted on the map. Data shown in Fig. 3 to be reported with the fuel rate versus torque map.

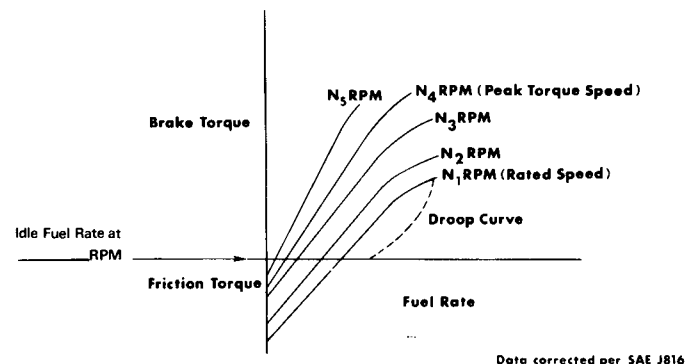


FIG. 2—FUEL RATE VERSUS TORQUE MAP