

Fuel Economy Measurement—Road Test Procedure— Cold Start and Warm-Up Fuel Economy

1. Scope—This procedure is a modification of the urban driving cycles noted in SAE J1082 and which is run on a suitable road or test track. The procedure yields cold start/warm-up fuel economy values indicative of consumer level at the ambient condition of the test. Within referenced limitations, the procedure can be utilized to determine the fuel economy differential among vehicles or between vehicle changes.

1.1 Purpose—This SAE Recommended Practice provides a uniform test procedure for measuring the fuel economy of light-duty vehicles during cold start and warm-up operation (motor vehicles designed primarily for transportation of persons or property and rated at 4500 kg GVW (10 000 lb) or less) on suitable roads.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1082—Fuel Economy Measurement Road Test Procedure

SAE J1263—Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques

2.1.2 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTMD4814—Standards Specification for Automotive Spark-Ignition Engine Fuel Petroleum Measurement Tables

2.1.3 OTHER PUBLICATION

Energy Policy and Conservation Act, Public Law 94-163, 94th Congress S.622, December 22, 1975.

3. Definitions

3.1 Driving Cycle—The urban driving pattern is defined by 8.3.4.2. This driving pattern is a modification for cold starting of the SAE J1082 urban driving cycle.

3.2 Test Vehicle—Passenger car and light truck prepared for test according to Section 7.

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3.3 Test Vehicle Weight—Unloaded vehicle weight (curb weight) plus 136 kg (300 lb).

3.3.1 **CHASSIS DYNAMOMETER INERTIA WEIGHT AND HORSEPOWER SETTINGS**—Should be established and set in accordance with SAE J1263.

3.4 Observed Cold Fuel Economy—Observed cold fuel economy will be reported for both 0 to 3.2 km (0 to 2 mile) and 0 to 6.4 km (0 to 4 mile) cycles. The 0 to 3.2 km (0 to 2 mile) observed fuel economy will be determined by dividing the 3.2 km (2.0 mile) of the urban cycle by the fuel consumed during Cycle 1. The 0 to 6.4 km (0 to 4 mile) observed fuel economy will be determined by dividing 6.4 km (4.0 mile) by the total fuel consumed during Cycle 1 and Cycle 2. Economy will be expressed in kilometers per liter (miles per gallon).

3.5 Corrected Cold Fuel Economy—Corrected economy is the observed economy multiplied by the correction factors listed in Section 11 and Section 12. Corrected fuel economy will be expressed as kilometers per liter (miles per gallon).

3.6 Correction Factors—Factors which are used to adjust data to the standard ambient condition of 15.6 °C (60 °F) and reference fuel properties.

3.7 Average Fuel Economy—Average fuel economy is the total distance driven divided by the total volume of fuel consumed in a series of replicate tests. When the distance driven in each of the tests is identical, as may be assumed for this procedure, the average fuel economy is determined by taking the harmonic average of the individual economies. See Equation 1.

$$\text{Average Fuel Economy} = \frac{n}{1/\text{mpg}_1 + 1/\text{mpg}_2 + \dots + 1/\text{mpg}_n} \quad (\text{Eq. 1})$$

3.8 Test Repeatability Guidelines—These guidelines are intended to provide an estimate of repeatability of test data for replicate tests (assumes a standard deviation equal to 1.9% of the mean).

3.8.1 **ESTIMATE OF THE 95TH PERCENTILE RANGE FOR REPLICATE TESTS**—The 95th percentile range (R) equals 0.019Q times the average fuel economy, where Q equals the critical value obtained from a table for the student t range and the average fuel economy for n tests.

Selected values for 0.019Q are shown in Table 1:

TABLE 1—SELECTED VALUES FOR 0.019Q

n	0.019Q
2	0.053
3	0.063
4	0.069
5	0.073
10	0.085

Example 1 (SI units)—If a vehicle obtains 6.20 km/L and 6.60 km/L on two tests on the same cycle, the corrected average fuel economy would be 6.39 km/L and the 95th percentile range would be as shown in Equation 2:

$$R = 0.053 \times 6.39 = 0.34 \text{ km/L} \quad (\text{Eq. 2})$$

The difference between the two tests is 0.4 km/L which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

Example 2 (U.S. units) - If a vehicle obtains 14.5 mile/gal and 15.5 mile/gal on two tests on the same cycle, the corrected average fuel economy would be 15.0 mile/gal and the 95th percentile range would be as shown in Equation 3:

$$R = 0.053 \times 15.0 = 0.80 \text{ mile/gal} \quad (\text{Eq. 3})$$

The difference between the two tests is 1 mile/gal which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

3.8.2 ESTIMATE OF THE AVERAGE FUEL ECONOMY AT A 90% CONFIDENCE INTERVAL—See Equation 4.

$$\text{Average at 90\% Confidence Interval} = \text{Average Fuel Economy} \pm \left[\frac{0.031}{\sqrt{n}} \times (\text{Average Fuel Economy}) \right] \quad (\text{Eq. 4})$$

Example 1 (SI Units)—If a vehicle obtained 6.29 km/L and 6.46 km/L on two tests on the same cycle, the average fuel economy would be 6.37 km/L and the 90% confidence interval would be as shown in Equation 5:

$$6.37 \pm \frac{0.031}{\sqrt{2}} \times 6.37 = 6.37 \pm 0.14 \text{ km/L} \quad (\text{Eq. 5})$$

Example 2 (U.S. Units)—If a vehicle obtained 14.8 mile/gal and 15.2 mile/gal on two tests on the same cycle, the average fuel economy would be 15.0 and the 90% confidence interval would be as shown in Equation 6:

$$15.0 \pm \left[\frac{0.031}{\sqrt{2}} \times 15.0 \right] = 15.0 \pm 0.3 \text{ mile/gal} \quad (\text{Eq. 6})$$

4. Instrumentation—All instrumentation shall be calibrated.

- 4.1 Fuel**—The fuel measurement device must be compatible with the vehicle fuel system and should alter the fuel temperature and pressure as little as practical. The fuel measurement system must be accurate to within 0.5% of the fuel used during a driving cycle.
- 4.2 Speed**—The speed indicating device shall indicate vehicle speed in kilometers per hour (miles per hour) and be accurate within 1 km/h (0.5 mph).
- 4.3 Acceleration**—The acceleration indicating device must be capable of indicating both positive and negative acceleration. It shall indicate acceleration/deceleration in m/s² (ft/s²) and be accurate within 0.2 m/s² (0.5 ft/s²). (Refer to 6.5 for Chassis Dynamometer Testing.)
- 4.4 Time**—The time measuring instrument must be capable of measuring the time interval to 0.1 s and be accurate within 0.1 s in 1 min.
- 4.5 Temperature**—The temperature indicating devices must be capable of measuring to the nearest 1 °C or 2 °F. Accuracy must be within ±1 °C or ±2 °F. The sensing element shall be shielded from radiant heat sources.
- 4.6 Absolute Barometric Pressure**—An aneroid or mercury barometer should be used. This device should be accurate within 3 kPa or 0.1 in Hg.
- 4.7 Wind**—Wind speed should be measured with a device that provides an indication of wind speed that is accurate within 3 km/h (2 mph). Wind direction should also be indicated.

- 4.8 Distance**—A distance indicating device is required if the tests are not conducted on a premarked course. This device must be capable of indicating distance to within 5 m (15 ft) and must be capable of accuracy within 6 m in 1 km (30 ft in 1 mile).
- 4.9 Vehicle Weight**—Vehicle weight should be measured with a device that is accurate within 0.5% with a resolution of 5 kg (10 lb) or less.
- 4.10 Dynamometer Inertia Weight**—The dynamometer inertia weight is established reflecting the inertia of the nonrotating tires and the vehicle test weight. The inertia weight should be set to the nearest flywheel increment for mechanical inertia dynamometers, or within 5 kg (10 lb) for electrical inertia dynamometers.

5. Test Material

- 5.1 Test Vehicle**—The test vehicle shall be completely defined on the Test Vehicle Specifications and Preparation Form (Figure 1). (The test vehicle will normally be representative of a production built vehicle - any exceptions must be properly noted.)
- 5.2 Test Fuel**—Normally, service station fuel will be satisfactory for test purposes, provided that it is consistent with the manufacturer's recommendations for the vehicle and with the ASTM D 4814 standards. Gasoline octane rating, $\left(\frac{R+M}{2}\right)$ specific gravity or API gravity for diesel fuel or gasoline used shall be recorded. Other properties such as distillation and Reid vapor pressure should be recorded when available.
- 5.3 Lubricants**—Lubricants used shall conform to the manufacturer's recommendation for the predominant weather condition in which the vehicle is being tested.

6. Test Conditions

- 6.1 Ambient Temperature**—Tests and soaks should be conducted at ambient temperatures between -1 and 32 °C (30 and 90 °F). For temperatures below -1 °C (30 °F), the temperature correction factors may not be valid.
- 6.2 Wind Speed**—Tests must not be conducted when average wind speed exceeds 24 km/h (15 mph) or when gusts exceed 32 km/h (20 mph). During the soak period, higher wind speed is allowable.
- 6.3 Road Conditions**—Roads must be dry, clean, smooth, and not exceed 1.0% grade. If operating on a closed track, the start and stop points should be selected such that the schedule elevation difference is 3 m (10 ft) or less.
- 6.4** It is recommended that roadside markers be used to indicate the points at which speed changes are to be made as indicated in 8.3.
- 6.5 Driver's Aid**—A driver's aid is recommended for dynamometer operation reflecting the schedule in 8.3.

7. Test Vehicle Preparation

- 7.1 Break-In**—The vehicle should have accumulated a minimum of 3200 km (2000 miles) of operation prior to test. At least 1600 km (1000 miles) must have been driven at cycling speeds between 64 km/h (40 mph) and maximum legal highway speeds. If a closed track is available for break-in, the maximum speed should not exceed 160 km/h (100 mph). Chassis dynamometer break-in is acceptable. All of the tires must have operated at least 160 km (100 miles) road or track prior to the test. Tires must have at least 75% of the tread remaining and tread must be in good condition. Vehicles for dynamometer testing should have experienced at least 800 km (500 miles) of road cyclic operation.

- 7.2 Inspection**—The vehicle must be inspected and adjusted where necessary to meet manufacturer's specifications. Checks are specified on the Test Vehicle Specifications and Preparation Form (see Figure 1).

**FUEL ECONOMY TEST—LIGHT-DUTY VEHICLES
TEST VEHICLE SPECIFICATIONS AND PREPARATION**

SPECIFICATION LIST

DATE _____
 CAR NO. _____
 YEAR AND MAKE _____
 MODEL AND BODY _____
 VEHICLE IDENT. NO. _____
 PRODUCTION _____ OTHER _____
 ENGINE TYPE _____ DISP. _____
 NET hp (U.S.) _____ COMP. RATIO _____
 ENGINE NO. _____
 ENGINE EMISSION CALIBRATION NO. _____
 EXHAUST SYSTEM TYPE _____
 TRANSMISSION _____
 DRIVE AXLE TYPE AND RATIO _____
 BRAKES, (DISC OR DRUM) F _____ R _____
 STEERING _____
 *TIRE MAKE _____ SIZE _____
 LOAD RANGE _____ TYPE _____
 % TREAD _____
 COLD INFLATION-TIRE PRESSURE
 LF _____ RF _____
 LR _____ RR _____
 TEST WEIGHT _____
 *TIRES MUST HAVE A MINIMUM OF 100 miles (160 km)
 BREAK-IN ON ROAD OR TRACK

CHECK LIST

ENGINE OIL LEVEL OK _____
 COOLANT LEVEL OK _____
 TRANSMISSION FLUID LEVEL OK _____
 BELTS AND HOSES-TIGHT _____
 CHECK ENGINE CONTROL MODULE _____
 DIAGNOSTIC CODES _____
 THROTTLE OPERATION-FUNCTIONAL _____
 IGNITION WIRES-TIGHT _____
 BRAKE DRAG NOT EXCESSIVE _____
 TRANSMISSION OPERATION _____
 TIRE PRESSURE AND CONDITION _____
 ENGINE TUNE-PERFORMED _____
 WHEEL ALIGNMENT-PERFORMED _____
 AIR CLEANER-CLEAN _____
 A/C COMPRESSOR LOAD-REMOVED _____
 NO FUEL LEAKS _____
 FAN CLUTCH-FUNCTIONAL _____

$$\% \text{ TREAD} = \frac{\text{AVERAGE TREAD DEPTH OF TEST TIRES}}{\text{AVERAGE TREAD DEPTH OF IDENTICAL NEW TIRE}} \cdot 100$$

LIST POWER CONSUMING OPTIONAL EQUIPMENT

COMMENTS: _____

CAR CHECKED BY: _____**DATE:** _____**TEST FUEL SPECIFICATIONS**

FUEL TYPE AND GRADE _____
 GRAVITY (API OR SPECIFIC) _____ AT 15.6 °C (60 °F)
 REID VAPOR PRESSURE _____ kPa (psi)
 DISTILLATION 10% _____ °C (°F)
 50% _____ °C (°F)
 90% _____ °C (°F)
 OCTANE $\frac{R+M}{2}$ _____

FIGURE 1—FUEL ECONOMY TEST—LIGHT-DUTY VEHICLES
TEST VEHICLE SPECIFICATIONS AND PREPARATION

7.3 Instrumentation—The fuel measuring device, temperature indicating devices, and other instrumentation, as necessary, must be installed in a manner not to hinder the vehicle operation or operating characteristics.

7.4 Test Weight—The vehicle weight must be adjusted to provide the test weight indicated in 3.3 (this test weight includes instrumentation and operator).

7.5 Tire Pressure—The cold tire pressure should be the minimum recommended by the manufacturer for the vehicle test weight.

8. Test Procedure

8.1 Preconditioning—The vehicle must be driven a minimum of 32 km (20 miles) at 90 km/h (55 mph) or maximum legal highway speed to stabilize engine and driveline operating temperatures immediately prior to the cold soak.

8.1.1 COLD SOAK—The vehicle should be parked close enough to the start of the test course to fulfill the requirements of 8.3.4 and exposed to ambient weather for a period of not less than 12 h nor more than 24 h prior to the beginning of a cold urban test. The temperature of the engine oil, engine block coolant, and/or ambient air is to be recorded just prior to the start of the test. In areas of rapidly changing ambient temperature, all three temperatures should be recorded and should not vary by more than 6 °C (10 °F) for a valid test.

8.1.2 START PROCEDURES—SPARK IGNITION ENGINES

8.1.2.1 Manufacturer's Recommended Procedure—Where the manufacturer has specified a vehicle starting procedure, that procedure should be followed.

8.1.2.2 Where no recommended starting procedure is specified, the following procedure is recommended. Deviations or other starting procedures should be documented.

8.1.2.2.1 Manual Choke Equipped Vehicles—Vehicles equipped with manual chokes will be started by slowly depressing the accelerator pedal fully to the floor while simultaneously adjusting the choke to the fully closed position. Release the accelerator pedal and start the engine. When the engine is running, release the choke only to the point where the engine continues to run smoothly. The choke should continue to be released during the driving cycle as rapidly as possible while maintaining smooth operation.

8.1.2.2.2 Automatic Choke Equipped Vehicles—Vehicles equipped with automatic chokes will be started by turning the key to the ON position, then fully depressing the accelerator and releasing, and starting the vehicle. After the vehicle has been moved to the starting position, tap the throttle lightly to reduce the idle speed.

8.1.2.2.3 Fuel Injection Equipped Vehicles—Vehicles equipped with an FI system will be started by turning the key to the ON position, then starting the vehicle. No effort to reduce idle speed should be made.

8.1.3 START PROCEDURES—DIESEL ENGINES

8.1.3.1 Manufacturer's Recommended Procedure—Where the manufacturer has specified a vehicle starting procedure, that procedure should be followed.

8.1.3.2 Where no starting procedures are recommended, the starting procedure used should be documented.

8.1.3.2.1 Vehicles Equipped with Glow Plug Lights or Other Preheat Warning Devices—Glow plugs are normally preheated via a separate ignition switch position or a separate actuation switch. Actuate the glow plug. When the glow plug light goes out or otherwise indicates the preheat cycle is completed, depress the accelerator pedal to at least halfway to the floor and hold, and turn the ignition key to start position. Release the ignition switch and throttle pedal when the engine has reached a smooth running condition.

8.1.3.2.2 Vehicles NOT equipped with Glow Plug Lights or Other Preheat Warning Devices—Glow plug preheaters are required to start automotive type diesel engines. Sixty-second preheats will generally be satisfactory at -1°C (30°F). Fifteen seconds of preheat will be sufficient at 32°C (90°F) ambient. After the appropriate preheat cycle, the starting procedure will be followed as previously stated.

8.2 Vehicle Controls—Air conditioning compressor, headlamps, and other switched accessories that consume power should be turned off unless required for safe vehicle operation. Air conditioning or heater/defroster operation required to clear windows should be turned off as soon as safe vehicle operation is possible. Previous to the preconditioning cycle, the vehicle's battery should be in a fully charged state.

8.3 Driving Schedules

8.3.1 GENERAL DRIVING INSTRUCTIONS

8.3.1.1 Vehicles incapable of attaining acceleration rates specified by the driving schedules will be driven at maximum acceleration until specified schedule speed is reached.

8.3.1.2 Vehicles with automatic transmissions should be driven with the transmission in a range that insures all forward gears can be automatically engaged. If transmission hunting is encountered at a specified acceleration, the acceleration should be increased to maintain the transmission in the lower gear and this departure from the schedule noted on the data form (see Figure 2).

8.3.1.3 Vehicles equipped with manual transmissions will be operated in the following manner: Idles will be made in gear, clutch disengaged. Decelerations will be made in gear, and the clutch will be disengaged at 24 km/h (15 mph) on a stop. All cruise operation should be in the highest gear that will prevent engine lugging. Downshifts will be permitted to obtain specified acceleration rates after a deceleration or to obtain a smooth engine operation at a slow speed. The following manual transmission shift speeds are guidelines only and may be modified up or down as necessary to ensure that the specified acceleration rates are attained and to avoid engine lugging or overspeed. Departure from the shift speeds specified in Table 2 should be noted on the data form (Figure 2).

TABLE 2—MANUAL TRANSMISSION SHIFT SPEEDS (MPH)

Acceleration Upshifts	Vehicle Speed
1–2	15
2–3	25

8.3.1.4 Vehicle with truck-type manual transmissions containing a creeper gear will not use the creeper gear during the driving cycle.

8.3.1.5 Vehicles with manual transmissions will be shifted during accelerations at the specified speed (mph) shown in Table 2. Manufacturer's alternative shift schedules or shift indicator light shifting can be used if the specified driving schedule can be maintained.

8.3.1.6 During cruise modes, use the highest possible gear consistent with smooth engine operation.